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Solar Physics. Astrophysics, and Astronomy

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Tectonophysics

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Ravid C. McAdon (Lordynamics Branch, Lordard Space Fight L'enter, lincetail), Maryland 20171)

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PALEOMORTIEM AND MESOZOIC-CENTZOIC

PALEOMORTIEM AND LOCAL SOLO

A method of making paleoconclustral reconstructions based on ocean-lionc magnetic anomaly dela and inst-based paleocapatic data is brisily deactibud and its limitations susuad-Synthetic polar wender paths for the pariod 20-100 Mm are presented for Australia, Anterctica, India, Africa, Eurosia, North Asselca and South America, Comparison is made with observed paths, surept for inference, for which the data are too paccas. There are no significant differences between observed and synthetic paths. Just of locionation amonaly against paleoistitud shows a large graphis grid on continents (cansowalism). The absence of ony systematic trend to this scatter with time suggest that the lield has had the same average behaviour over the past 150 Mm and that lergy-acada supencion of the Barth cannot have occurred in this period. Such America has undergrees the least theage in position rejective to the pose in the past 100 Mm.

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J. Gasphys. Rea., Red., France 2002-201 (Peteococitsantal maps). J. Gasphys, Rea., Red, Fapar 180459

Volcanology

8699 Volsseelogy
MODELING THE THREE-DIMENSIONAL STRUCTURE OF
NACTOSCOPIC MAGNA TRANSPORT SYSTEMS, APPLICATION
TO SILMIN VOLCANO, MAMAIL
Hitheri Syan (Department of Mineral Sciscoss,
Machington, D.C. 20540), Robert T. Koyangs and
Birhard S. Yigha
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We treat the message of the systems.

washington, D.C. 20540), Robert T. Koyangi and airhard 3. Fishs

Pe teport the results of modeling the threedismonional internal structure of Klissan's magnetic pasequerys. The approach uses a cluer pissigiase model somisining squality-spaced levels upon
which wail-located sustain hypocenture are pictimalApplication at semetralining sologic and geophysisal retretts to this distributed soless of
antihogates permits the interpretation of salenic
attructures produced by instauring is response to
incelly high likel produces. The lollowing magne
expanore and storage attentance have been identifed within and beneath Elianues.

Fixury renduct. The conduit transporting magne
into Klisups's summit storage reservoir rises from
the model hous [14.8 km] to the 6.3 km dapph level.
to is some of letwes fracture ing and inferred
istruction, whose harizonist sections are salispical
in planform. Over its balge, the average market
aits at the component horizontal soctions in 1.3
km, with an average minor mile of 1.7 km. This
juicks an espect ceits of \$ - 0.22, & the 14.6 km
level, the strike of the major sale to the form.

Daring passage from the upper mantle through the

wants, oncil the accits (a H 4 TW of the 3.5 am lays).

Magna chamber compine licer. The interval free 6.5 to 5.7 km, immediately over the prisery conduit, is massissic. This suggests differentially high livid-lo-roch ratios, and raistively wech pathways for lutther restical crampport into higher israis of the account for the first constant of the storage complex as well as lateral laskage mastered into the Mauna Uie staming area—lor later vertical ascent hemmath the upper seat cift some. Salmaicity within the immediately subjected rocks that lors the lateral default (at 6.5 km) suggests that the laterand magna-rich boriton lares the effective floor of the primaty conduit (at 6.5 km) suggests that this interved magna-rich boriton lares the effective floor of the summat saccess complex. Haspan chumber oroum. Interes maissicity over the 1.1-1.6 has depth interved defines an elliptical region to place where. The top of this region de selon her a house an average minor asis of 1.5 km, and as average minor asis of 1.5 km, and as average minor asis of 1 thes, producing an separate catio of 2 m G.73. This region colocides

and an average minor nais of i.t ion, producing on sepect catio of \$\xi\$ = 0.73. This region colorides with the epicencral position of aumnic vertical displacement maxima during inflationary delotation and is interposited as a cepten of interposited and is interposited as a cepten of interposited and in interposited as a cepten of interposited and interposited as a cepten of interposited to position.

Boper sant rilt some pips. From a depth of 5.7 to ... explination region of relamicity rises becomet the burger sent rift some of the los paper sant rift some with the subhorizontal upper maxt rift some duct. This pips-like now has a sem diameter of 1.4 to and a vectical axis that plaress che surfece of the volume a yeten and the upper section of the Kose fracture system and the upper section of the Kose fracture system and the upper section of the Kose fracture system and the upper section of the Kose fracture system and the upper section of the Kose fracture system and the upper section of the compact; and quarrent face section of the compact.

storage reservoir, and quar-surface movage compact-mants and ducts in the upper east rift sobs. In this role, I he pipe is suggested to have contributed beguity to Hauns Ulu's magas supply during 1969-1972.

The model of megma transport and storage thus constructed provides a context to which other types of date (s.g., ground deforation and electrical conductivity) may be interpreted as well is a mesma of reliving petrological interpreted as well in a mesma of reliving petrological interpreted as well in a mesma of reliving petrological interprete such as transport.

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General or Miscellaneous

9220 New Fields
ASSIFER THENAL ENERGY STORAGE-A HUMERICAL SIMULATION OF ADDRES UNIVERSITY FIELD EXPERIMENTS.
Chie Fu Tesan (Learneece Berkeloy Leboratory,
Earth Sciences Sivision, Berkeloy, CA 94720)
Thomas Succheck, Christine Doughly
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of two systes of a musural squi(er thereal
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by Address in the field date. A general dour
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Editorial

Proposed New Journal: Tectonics

There is e fundamental and urgani need for a high-quality International Journal in teclonics. The literature is growing repidly, and the best pepere are spread through a wide renge of journats such as Journel of Geology, Red JGR, Tectonophysics, GSA Bulletin, EPSL, Geological Magazine Geology, Geophysical Journal of the Royal Astronomical Society, Geological Society of London Journel, end American Journal of Science. A top-flight international journal in lectonics with the highest refereeing elendards would ettract the vary best papers end would repidly gain acceptance as the prestige place to publish the best in ensisticat synthetic, and integralive tacionics. It would be e journel to be reed by elmoet everybody in regional geology, etructure, lecionics, geophysics and hard-rock geology. Cere would be needed to ensure that it did not herm the red JGR or GRL, which could be accompliehed by defining the goals of the new lournal so that everyone understood the kind of papere that would be considered. This could and should be done by excluding short noise and restricting papers for the new lournal to the field of tectonics aeneu-stricto, i.e., the structure and evolution of the terrestriel lithosphere, with dominant emphasis on the continents. Pepers on mantie convection, tidal friction, solid earth selemology, mentle end core petrology, and origin of the earth's magnetic field, for example, would thus be excluded. One could have the journal leen very heavily though not exclusively loward the structure end evolution of the continental lithosphere (dominently the continental crual) and give the journel e strong siant towerd integrelive tectonics, atructurel geology, and meleriale science but discourage, for example, rock mechanics and earthquake prediction, which would go to the red JGR. I thus vieuelize e more continental, more geological, and less geophysical emphasie in a journel of tactonics. There would be some overlap with the red JGR but not s greet deal, in no sense would this be a letters journal, competing with GRL. We have a superb opportunity to found a scholasticalty excettent journal that is reatly needed in earth science, Tectonics is one of the central cores of serth science today, and yet we do not heve a journel devoled exclusively to it.

State University of New York et Albany

Comments Requested.

The Publications Committee solicifs your comments and suggestions on the proposed new journal described above by Prolessor Dewey. According to present plans, AGU could publish this journel on a bimonthly schedule et a subscription price to AGU members of \$15-\$20 per yeer. In order to hold subscription prices down the journal would be limited to the equivalent of 400 JGR pegee per yeer, but it would probably appear in e pege size smaller then that of JGR. A high rate of rejection of menuscripts might be needed to limit the efze of the journal while mainfaining reasonably rapid publication. There would be no page charges, but only euthor-produced copy would be published. As is the cese for author-produced pepera in other AGU journele pepers would be copy edited before eulhore prepared cemers-ready copy.

The Publications Committee feels that this proposed journel le scientifically worthwhile, le tergeted on a repidly growing field that lacks a publication locue, end will probebly be a greet success. More generally, we believe that geophysicists may welcome inexpensive, multidisciplinery

journale oriented toward perticular ereas of research. Please send your comments and auggestions to me et

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> > James C. G. Walker Cheirmen, Publicatione Committee

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Cover. A view of the Inner Harbor, one of the major attractions h Baltimora, hoat city for the 1981 AGU Spring Meeting.

Nd Isotopic Studies: Some New Perspectives on Earth Structure and Evolution

Donald J. DePaolo

Dapartment of Earth and Space Sciences University of Celifornia, Los Angales

This erticle ie the text of a talk presented in the Frontiers of Geophyeics session at the 1980 AGU Spring Meeting in Toronto, Cenede.

introduction

Geochronology is generally regerded as a branch of geochemistry that focuses on the determination of the eges of rocks. Although the reliable determination of eges of rocks is no iriviel tesk, the ebove definition of geochronology le overly restrictive because the long-lived redioective nucitdes that can reveet the ege of rocks cen etso yield a unique type of informetion about the internal structure of plenels end the processee by which thei etructure is formed. In the case of the earth end the terrestriet plenete, the internal etructure can be described grossly by the division into core, mantle, cruel, end an elmosphere-hydroephere system where present. The present state of the earth (moon, Mars, etc.) can be studied by a number of methods, including photogeologic, petrologic, and chemical characterization of cruetal rocks, and geophysical studies of the Interior through the use of seismicity, gravity, heet flow. and other melhods. But when end how this structure formed cannot generatly be escertained by those methods except by inference from theoretical models. The time dimension is uniquely accessible through the study of variations in the natural abundances of radioactive elements end their decay products, i.e., through geochronology. By using information about the geochemical properties of the elements, coupled with the meesured isologic variations, the nature of plenetery differentiation processes and the associeted time scates can be interred. Such information is critical for linking what la known about the present structure of the earth to modets of its evolution over the pest 4.5 billion years. There is, however, an importent restriction to the applicability of isotopic measurements, and that is thet only If the geochamical properties of the particular elements are wett understood cen isotope ebundance variations caused by radioactive decay be translated into information on planelary evolution.

For Ihis reason there wee graal excitement when, in 1974 end 1975, Günther Lugmair, Kurt Mertl, end Normen Scheinin of the University of Celliornie, San Diego, chemistry department were able to determine the age of the besetfic meteorite Juvinas and e luner basell, using the decey of Semerlum-147 (147Sm; hell lile = 106 eons) to Neodymium-143 (143Nd) [Lugmeir et et., 1974, 1975]. The excitement elemmed from the lect that these two elements, Sm end Nd, were rere-earth elemente (REE), end this group of elemente, found in trace emounts in all rocks and minerals, hee been the subject of Intensive study over the past two decades, beginning with the ploneering studies by Romen Schmitt, Lewrence Haekin, end coworkers [Heskin et el., 1966] and continuing with increesing sophistication to the present (rare-earth geochemietry has recently been reviewed by Heekin and Pester [1979]). Presently the REE are by fer the beel understood trece elemente in lerms of their behavior in planetery processes. In eddition to being well understood, Sm and Nd also heve properties that are much different from the perent-daughter element paire thet had been previously used in geochronology, meinly U-Pb, Th-Pb, end Rb-Sr. They therefore promised to give an entirely new perspective on earth evolution. Shortly after the work of the UCSD group, the system was applied to terrestrial rocks [DePeolo and Wesserburg, 1976e, b; Richard el el., 1976; O'Nions et el., 1977] and hae yielded a large of exciting results. The purpose of this article is to briefly describe the most important findings of these aludies to dete, and their implications for models of the structure and evolution of the earth's mentile and cruet. If should be noted that the Sm-Nd system is the first geochronometer to come into use when the geochemietry of the parent and daughter were elready welf known. This facilitated its immediele use ae e geochemical trecer rether than purely ae e tool for determining the age of rocks. Sm-Nd elso rapreeente en excellent exemple of e method originally developed for studies of lunar rocks that has paid greet dividends in terrestrial applications.

The isotopic Record of Planetary Evolution

The uniqueness of the information yielded by Sm-Nd Isotope eludias can be understood by coneidering the differencee between Sm-Nd and the various other geochronometere. One of the more important differences is lilustrated in Figure 1. The time axis in each greph is age; thei is, time measured backwards from the present. The verticel axie is the ratio of the radiogenic leotope to another isotope of the same element that is neither radiogenic nor redioective, the letter being used as a normelizing abundance. These relios increase with time as the radiogenic isotope accumulates from the decay of the perent. The rate at which the ratio inoreases in e given environment is proportional to the abun-

dence of the radioective perent retelive to the normalizing leolope of the deughler element (referred to ee the parent/ deughter ratio), Changes in the slopes of these evolution lines are therefore related to chemical frectionalion of the parent and daughter elements. Although not the primery subject of this article, a good exemple of how the isolopes track earth evolution to the U-Pb system (Figure 1). The Isolope 208Pb is the product of 238U decey, so the slope of en evolution line on Figure 1 (bottom) is proportionel to ²³⁸U/²⁰⁴Pb. This relio is known to have been very emelt in the soler nebule, as evidenced by the precent solar ebundancee, so the evolution curve shown for the nebule (tabeied SN) hee e emell slope. As the nebule condensed, U-which has a high condensation temperature-probably condensed earlier Then Pb, which has a low condensellon temperature. If the earth accreted before all of the Pb condensed, or if Pb was losi by volatilization during accretion, then the earth would have formed with a U/Pb ratio higher then thel of the SN when it accreted ~4.5 eons ago. This is shown on Figure 1 (boilorn) by the increesed slope of the earth curve, ioilowing condensation and accretion (CA).

Further irectionation of U from Pb could heve occurred in the earth as a result of core formation (CF), bacause the lendency for Pb to occur as e sulfide could have resulted in its enlering tha core in lerge emounte, while U would heve been excluded from the core. The result: a high U/Pb silicate portion of the earth (mentle end cruet) end a low U/Pb core. Subsequant to core formetion, magmatic proceeees in the ellicate portion cen cause formetton of domains of somewhet higher end lower U/Pb to lorm, shown by the diverging arrows. The present average velues of 206Pb/201Pb tound in the earth's crust (C) and upper mentle (UM) and their reletionship to the value for the lotal earth ((+)) end tho sun era shown on tha T = 0 axis of the graph. (Note that the earth value le eciuelly unknown because the changes In U/Pb that ere ceused by core formetion as opposed to condensetion and accretion are not known.) The kinks in the curves, corresponding to changes in U/Pb, are the Ilmes that are recorded with most sensitivity. Thus the U-Pb system gives very precisa information on the time of tormation of the earth and/or core formation but is less senal-Ilva to the time of separetion of the crust from the mantia because little change in U/Pb is involved in the latter procesa. In lact, the U/Pb system yielded the lirst accurate estimate of the age of the earth, as well as the most precisa estimate aveileble loday. The situation for Rb-Sr is somewhel different (Figure 1 (middle)). Rb is substantially mora votatile than Sr under the conditions that prevailed in the SN, end the earth apperently inherited e Rb/Sr ratio about 10 times smaller than the sun's. But frectionation during core formation is less tikely, so Rb-Sr pracisely fixes the

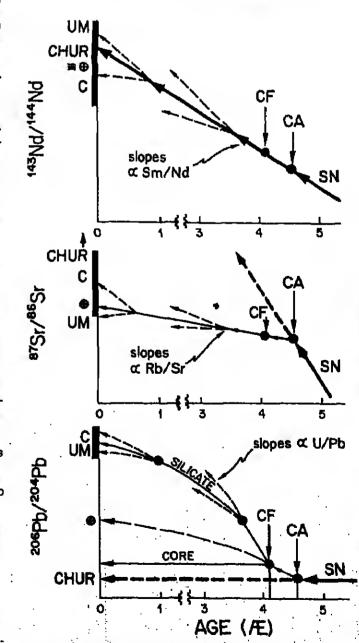


Fig. 1. Growth of Pb, Sr, and Nd Isotopic ratios with time in the solar nebula (SN) and the earth (\oplus), showing the effects of the original condensation of the nebula end ecoration of solic bodies (CA), core formation in the earth (CF), and subsequent magmatic processes within the earth. On the T=0 axis are shown the retetive present-day values of the isotopic ratios for the earth's upper manile (UM) and confinental cruat.(C) and their relationship to the values in the earth, sun (SN), and the chondrillo meteorites (Chur). Only for Nd do the present vetues for the earth, sun, and chondries correspond. Nd isolopic vertetions measured in rocks therefore reliect only the megmatic processes that have caused the earth to evolve the present structure of its mentle and crust.

Fig. 2. The evolution of the 143Nd/144Nd ratio in the earth's manile la datarminad by measuring the prasant-day valua of 143 No. 144Nd to rocks from the crust and correcting for the rock's aga, which also must be detarminad. Initial ratios, calculated for rocks of verious agas, are used to define the 143Nd/144Nd in the mantle os a function of itme. By comparing those to the chondritic maleorito curvo (Chur), information is obtained about the evolution of mantle atructura through time.

tima of the eerih's formetion. Subsequent maginetic procosses have also fractioneted Rb end Sr by larga factore, eo fhet information on the age of the cruet is also given by Rb-Sr. The present erSr, eeSr ot cruet and upper mentle presumebly straddia the oarth vetua, but the exect earth velua is unknown beceuea essenifalty atl maleriels of the eerth's surfeca have been affacted by magmatic fraction-elions et some time. Tha evolution curves for ^{e7}Sr/⁸⁶Sr are atmost skalgini lines boceuse the hall-lile of ^{er}Rb ts so tong $(50 \text{ aons } \approx 50 \times 10^9 \text{ yr}).$

The Sm-Nd systam le diffarent because both Sm and Nd probably condensed from tha soler nabula et tha eame tima, end neithar would have entered the core, so there was no fractionation of Sm from Nd at those ilmae. However, subalenilei fractionetion of Sm from Nd does occur in magmatic proceeses, end essentietly only in magmatic processes. Consequantly, Iha Sm-Nd aystam givea no information on the age of the earth, but, on the other hand, it provides an excallent maans to study tha magmetic differentiotion of the plenel without complications thet relate to Its original formation. A good astimate of the present-day 144Nd for the totel earth is provided by measurements on the chondrillc moteorites [Jacobsen end Wasserburg, 1980]. This basefine value is anormously valuable. For instence, the complementary nature of the present-day 143Nd/144Nd values for the earth's upper mentle and conlinental crust ts raadily apparent in Figura 1 (top). Estimates of the emount of Nd present in each reservoir have therefora allowed a mass balanca between the crust and the mentle, simply using the levar rule, so that the amount of tha mentle that has been involved in producing tha crust



TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

Tha Waakiy Nawspaper of Geophysics

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could be calculated (see below). The Sm-Nd method adds e new, end much needed, dimension to isotopic studies of plenetery evolution.

The Evolution of the Earth's Mantie

The epplication of the Sm-Nd method to problems of the history and structure of the earth's mentle is illustrated in Figure 2. Measurements of the 143Nd/144Nd retio in oceanic volcanic rocke, all of which are relatively young in comparison with the age of the earth, end in young continental rocks give an indication of the velue end the veriebility of this ratto in the upper mentle todey because the rocks represent solidified magmes that are presently coming from the upper mentle. Older rocks ere present in the continental crust, and can be used to defermine the 143Nd/144Nd in the mentia et various times in the pest. The assumption is thet elf of the rock meterials that make up the continente were, et one time, derived from the mentie as magmas, which solidified end have remeined neer the surface because of lihelr low density. As shown in Figure 2 (bottom) the 143Nd/ A4Nd retto is meeeured in e rock semple end then correctad for the rock's age back to en 'initiel' value which represents the 143Nd/144Nd retto the rock hed at the time it came from the mantle. The slope of the ege-correction vector is proportional to the Sm/Nd ratio measured in the rock, as in Figure 1. The initiel retios can then be compared to the Nd/144Nd growth in e chondritic environment (celled 'CHUR' for chondritic uniform reservoir). Devietions from this curve, usually expressed as the peremeter \mathbf{e}_{Nd} (in units of 0.01%), ere indicative of chemical differentiation in the manile and can be interpreted in terms of models of eerth evolution. Recovering information about the mentile from rocks in the continental crust can be a tricky business and requires e considerable emount of geological insight, which comes from other types of etudies of the rocks. A perticular problem is that some igneous rocks do not represent megmee derived from the mentle bul, rether, appear to ba melted from the cruet itself. Such rocks can give no information ebout the manile. On the other hand, the 143Nd/144Nd initial retios cen often be used to identify magmas derived from the cruet, e problem of considerable interest, especially for eoma magmas that contain economically importent amounte of ore metals such es gold, sliver, copper, and

initiel 143Nd/144Nd retios that heve been determined on rocke which era suspected of being derived from the manlie are shown on Figure 3. The most obvious conclusion is that the date fit the CHUR curva rather well. This indicates that the Sm/Nd retio of the mentle, end praeumebly the whole earth, is assentially exactly that of the averaga chondritic meteorite, where 'exactly' meens ± 2% or 3%. The demonstralion of euch a close correspondance between the relative ebundance of two alements in the earth and chondritas is unprecedented end offers support that chondritae provide e meaninglul model for tha aarth's composition, at least lor some elements that are nonvolatile and nonmatallic in their geochemical behavior.

The minimel ecatter about the CHUR line, especially for rocks older then about 2 sons, le elso noteworthy. It indicalee that the mentle started out with e uniform composition, probably because of the mixing effect of rapid convection when the earth was hotter, during its early history. The uniformity contrasts sherply with the pronounced leyaring in the moon avidenced by analogous data from luner rocks (Figura 8). Younger rocks exhibit increasing ecatter, mostly ebove the CHUR line, indicating that chemically different domains evolved greduelly in the mentile as opposed to being formed early and persisting through tima.

The Age of the Continents

Whan continental crust forms, it generally is fractionated chemically, relative to the mantia, including having a Sm/ Nd retio about 40% lower on avarage. Consequently, Ita subsequent isotopic avolution le along a vactor of proportionally lower slope, as shown in Figure 3 for crust formed 3.8 eona ago. In cesae where crustal aga wes not previouely known, the Intersection of the crust avolution vector with the CHUR curve givee the age. This model age is called T_{CHUR}. Interestingly, no rocks have yat been lound with interaactions that correspond to an ega greater than 3.8 eons. Thue the oldest rocks known are about 0.75 eons younger than the age of the earth. The Sm-Nd dala confirm that this aga gap is real and not merely the affect of 'rasetting' of isolopic eges at more recent times, which can

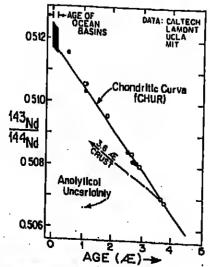


Fig. 3. Measured initial ratios for crustal rocks, showing a closs tit to the Chur curve, with increasing scatter at more recent times. Note that the total change in 143Nd/144Nd over the entire history of the earth is only about 1%, but the analytical uncartsinty is attill

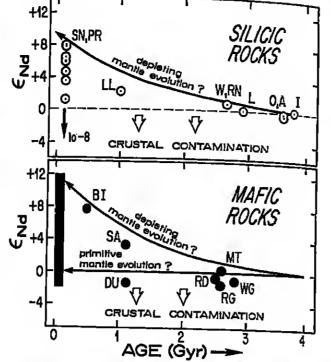


Fig. 4. Daviations of the initiel 143Nd/144Nd ratios from the Chur curve (from Figure 3), expressed se e_{Nd}—tha fractional difference in units of 0.01%.

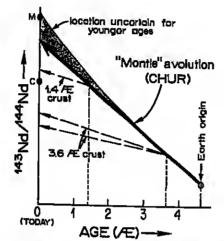


Fig. 5. Model for crust and mantle Nd isotopic avolution. Crust forms by axtraction of chemically frectionated metarial from the mantia and avolvae along linea of lower alona, reflecting few Sm/ Nd ratios. The residual mentia, with increased Sm/Nd, must evolve away Irom CHUR in the opposite direction. Present values of 143Nd/144Nd in average crust (C) and in midocean ridge basels (M) are also shown.

eometimes obscure the true age. T_{CHUR} ages are not sensitive to later tectonic disturbancae, as ara many other radiometric agaa. The explanation of this daley in the formation of crust is still not agraed upon. Presently favored is the idee that the early earth was so hot, and convection so rapld, thet cruet was unetable, being destroyed and remixed into the mantle as rapidly as it formed. Only after the sarh cooled sufficiently could crust be preserved. An alternative hypothesis that the earth sterted cold and required time to heat up to the point that malting could occur in the interior and crust formation begin is considered less likely.

The deviations of the dete points from the CHUR curve ere megnified in tha ϵ_{Nd} -time diagrams of Figure 4. The increasing deviatione at mora racent times are cleerly shown. The mefic rocke, besalt and gabbro, have petrologic charecteristice that ere consistent with their coming directly from the mantle ee magmae. They could be considered the best semplare of the mentle. On the other hend, the slikic rocks, granite, grenodiorite, and related rock types, heve patrologic cherecteristics that auggest they are not directly derived from the mantie. However, ellicic rocks eppear to make up the bulk of the continental crust and ere therefore Important for determining how crust le formed. If the manile had retained a chondritio Sm/Nd ratio throughout the earth's hietory, all of the points would be expected to fall st $\epsilon_{Nd} = 0$ for all times. The deviations from $\epsilon_{Nd} = 0$ indicate that of least some perts of the mentile have ecquired an Sm/Nd ratio different from chondrilic. Since most of the de-> 0), the implication is ins parts of the mantle have Sm/Nd higher than chondritic.

A elmpla axplenation amergee if one recalls that the continentel crust has low Sm/Nd. It is also enriched in both elsmente, ralative to the mentia, by a factor of about 25 for Nd and about 18 for Sm. Consequently, it is clear that as confinental crust forme the mantle loses Nd at a greater rale than Sm and hence acquiree a higher Sm/Nd retio. The curved lines in Figure 4 show how the ϵ_{Nd} of the mantle would evolve ee its Sm/Nd graduelly increased as a result of the growth of the crust. The overall model is illustrated in Figure 5, where the complementary neture of the crustal evolution lines for ¹⁴³Nd/¹⁴⁴Nd (dashed) and the mention evolution (ehaded) is shown. This model for the reletionship between the chemical composition of the crust and complemantary changes in the composition of the mantle is intultively simple and, in fact, seeme almost trivial. But, eurprisingly perhape, this coneideration had until recently received tively little attention, for the reason that with the other lectope eyeteme tha complementary changes in the mantis could not be identified because the sterling-point composition was unknown (as ehown in Figure 1). The Sm-Nd isotope system provides the baseline—the $\epsilon_{Nd}=0$ line (CHUR), and the systematic deviatione shown in Figures 4 and 5 represent the first deta that cen be used to quentily the complementary nature of the continental crust and the mantle from which it was extracted. Furthermore, the isotopes are better tracere for this purpose than chemical trails, because they are intensive and see through the chamical changes that accompany the formetion of magme

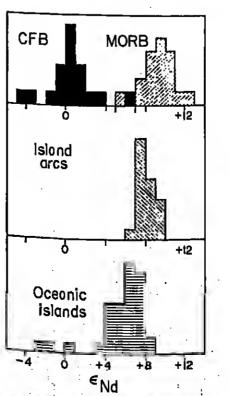
Basallic Volcanism and a Model for the Structure of the Mantie

The ENd-time date are one side of the evidence that has fed to a rather simple picture of the structure of the mantle and its relationship to the crust, depicted in Figure 7. The other side is shown in Figure 8, a histogram of ENd velues measured in young beselte. This figure shows the distribution of some of the data within the heavy solid bar in Figure 4 (bottom). The important characteristics of the deta ere: (1) basalts (or andssitee) of e given tectonic setting have a characteristic value of ENd, with a finite veriability of ebout ±2 or 3 units, (2) elmost all oceanic bassits heve ENd between +4 and +12, and (3) continents flood bessits, volumetrically the most significant menifestations of beseltic volcanism on continents, heve end distinctly different from the oceanic basalte end cluster et $\epsilon_{\rm Nd} \approx 0$, the velue characteristic of undifferentiated mentie. Taking these values to represent the s_{Nd} of the mentle domeins from which the besalis come, the oceanic laves clearly show the depleted (in Nd relative to Sm) neture of the mentle, se expected. The conlinental lavas, however, appear to require that some parts of the mantle are attil in a relatively pristing etate and have not been effected by extraction of continental crust. Furthrmore, there is simply the puzzling difference between confinental and oceanic regions, independent of the meening of the ectual velues.

One of the most interesting aspects of these date is the relatively tight clustering of ϵ_{Nd} values for each group, evan though the points represent e worldwide sampling. This indicates, for instance, that the mantle 'reservoir' from which midocsan ridga baselts coma is relatively well mixed on e global scale—and on a time scale that is short in comperison with the ege of the crust. This also eppeers to hold true for faland erca and intrepteta oceanic islands, aven though such has a mean ϵ_{Nd} that differs from the rocks of the other iscionic settings. Clearly, these observations must be teken into account in any modal of the structure and dynamics of the earth's mentle. However, at the present state of knowledge it is far from clear how best to model the date.

Wasserburg and DePaolo [1979] took a geometrical approsch, visualizing the earth as a series of boxes, each with a characteristic ϵ_{Nd} and each representing a possible source for basalt magmas. These boxes then had to be arranged in e way so as to produce the observed distribution of z_{Nd} values at the surface (Figure 7) and still be reconcitsble with continantal drift and plate tectonics. For example, one of the 'rules' used in constructing the model was that magmas erupted on continents muet always be different isotopically from those arupted in oceanic areas, but, in addillon, continents and ocaane must be allowed to change places almost instantaneously as a result of continental drift. The complementary nature of the continuntal cruet and the uppar (oceanic) mantle hed also to be taken into

The resultant model, in a simplified form, is shown in Figure 7. Basically, it is a two-layer mantle. The lower mantle is undifferentiated with respect to Sm, Nd, and other lithophile elements and, consequently, has reteined ite $\epsilon_{Nd} = 0$ for the enlire history of tha earth. The upper mentile continuously cycles through the process of ocean floor formetion at ocean ridgea and subduction, and, es e by-product of this cycle, new continental crust ta continually made in magmatic arce associated with the subduction zones by axtraction of chemically fractionated materiale from the mantie. The upper mantia today therefore has a positive ϵ_{Nd} (+12), which represente the integrated effect of making ow-Sm/Nd cruat over the past 3.8 eone. Thie positiva and is counterbalanced by the negative-end continental crust, estimated to eversga $\epsilon_{\rm Nd} \approx -15$. (The estimated everage values of $^{143}{\rm Nd}/^{144}{\rm Nd}$ in the crust and upper mantle are shown schematicsly in Figure 5, where the reletionship of the average cruetal 143Nd/144Nd to the average ege of that



hasalt, CFB—confinental flood basalt [from DePaolo and Wasser-

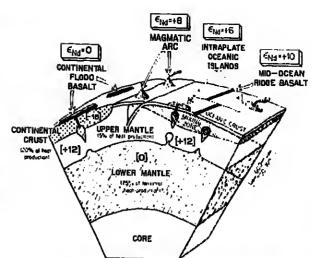


Fig. 7. Earth atructure model based on Nd leolopic deta. Continantal cruat la continuously producad in magmatic erce from that upper mentile, and presently the $\epsilon_{\mbox{\scriptsize Nd}}$ velues for the crust (- 15) and the upper mantia (+12) are complementary. The lower mantie does not directly take part in the cruet-producing process, but diapirs or plumae risa up from the lower mentle, producing intraplate basaltic volcantam and releeting juvenile gasaa to the etmoaphara. The depth shown for the upper-lower mentile boundary is a bost eatimate; the data would silow it to be alther shellower or deeper.

crust is epparent.) Since the mess of the continental crust le known to be eboul 2 \times 10²⁵ g, tha ϵ_{Nd} 's can be used to estimete the elze (thickness) of the 'upper mentia' pictured In the model. The crust has a Nd ebundance estimeted to ba about 50-60 times higher then the present upper mantia (which is depleted as a result of crust formalion), hence the mass of the upper mentle is celculeted to be about 100 x 1025 g.This corresponds to a thickness of about 600-700 km; only about one fourth of the mass of the whole mantle. Coincidentally, the calculated depth range corresponds to a marked seismic valocity discontinuity. This finding supports the suggestion that the seismic structure of the mantia may be raieted to chemical composition diffarances, and offers a possible explanation of the evolution of this structure. That various intermadiete values of ENd found in the oceanic basalta are explained in this modal as mixturas of materials from the two mantle leyars. Mixing occurs to a groat axtent in oceenic regions because of the presence of a shallow highly fluid zona where the mantle is near (or above) its melting temperature (low-valocity zona) but ganarally does nol occur in continental areas where this liuld zone is weakly daveloped or absant entiraly.

This view of the earth is allractive for several reasons. It is simple and yet can explain a large fraction of the observations, both isotopic and chamical. In addition, it adds a time perspective to the development of the layering in the mantla. An important implication of the model is that the radioactive elaments K. U. and Th. which are responsible for the heat generated within the aarth, are now highly depleted in the upper mantle because they are strongly partitioned into the crust when it torms. The lower mantle, howaver, still retains its original allotmant of these elements. Consequently, it appears that the heat-producing elemants have not been concentrated neer the plenet's auriace as had been praviously thought, but rather most (up to 75%) are etili retained deep within the earth. It also provides a picture of the convecting upper mantle being heated from balow. This arrangement effects both the modeling of convection in the mentile and the degree to which radiogenic heat production in the earth can be the driving torce for convection and its eurface manifestation-plate tecionics. The model also suggests that midocean ridge basalts ara blesed indicators of mantle properties, since they directly eample that relatively email portion of the mantle that has been most modified during the course of earth history.

An obvious test of such a model le whether it can explain other observations. Because Sr leotope ratios in basalts correlete well with ϵ_{NG} values (Figure 9), the Sr data cen clearly be considered consistent with the modal. A mora interesting test comes from a comparison with 3He/4He ratios In volcanic gasee. The leotope 3He le not produced in the earth in significant amounte, and therefore any theilie preeently coming out of the earth must date from tha time of tha earth's origin. Anomelously high 3Ha/4He ratios have been found eseccleted with midoceen ridges, oceanic islands, and some continental volcanic ereas, like Yellowstone [Craig et et., 1978]. This implies that the earth has not been already thoroughly outgeseed. The model of a lower mentia thet has bean more or less isolated from the earth's eurleca for ell or most of its existence is clearly consistent with the retention of gases deep in the eerth. Furtharmora, those basaite that appear to heve the greetest confribution coming from the lower mantle on the basis of end values also ere associated with the highest SHe/4He ratios. This correlation needs further documentation but is in the correct sense. A possible problem srea with the model involves Pb isotopes, where the model epoeere to be too simple to explain the deta. This mey be due to the likely situation thei Pb leotopes in the mantle ere strongly effected by the recycling of relatively smell amounts of crust back into the upper mentle. Also Pb isotopes could be affacted by any exchange of material between the cora and the mantie [Dupré and Allegre, 1980], Other problems with tha model include the nature of the seperation between upper manife end lower mantia, especially since some 'leakage' from one into the other is necessary to satisfy the observations. Also, the mixing origin of the and velues intermediate between 0 and +10 could be questioned. A priori, one might not expect clustering of intermediate values if they are mixtures of two end-member compositione. Although there ere problems, if is neverthelese surprising that a reasonably simple model can explain eo meny of the observa-

The Earth vs. the Moon

The Sm-Nd isotope eystam has also ellowed comparison of the early hietories of the earth and the moon in a way that was nevar bafore possible. Whan the initiel ϵ_{Nd} veluee of lunar besalle are plotted in the same way shown in Figure 4, they show a lerge dagree of acatter ebout the Chur curve (Figure 8). This scattar is much greater then that ehown by lerraetriel sampfae of equivalent ega. Taking the luner besalts to be representetive of the ϵ_{tid} values in the luner mentle, it is class that the moon become a highly heterogeneous body very soon after it formed. In contrest, that earth wes apparently quite homogeneous throughout the first 1 to 1.5 sone of its existance. The current interpretetion of this rather drastic difference is that it is raisted to the size of the bodies. The moon, which has only one sixth the maes of the earth, was haated sufficiently by the raleasa of gravitational energy for maiting to take piece soon efter eccrafion. This melting resulted in the formellon of the lunsr cruet, which has a low Sm/Nd like the tarrestrial crust, and complementary mentile layers with high (but variable) Sm/ No [cf. Taylor, 1975]. The earth also probebly beceme hot enough to mail very early. The moon, however, cooled rotallvely quickly aftar the initial burst of heet, end the leyered structure became permenantly 'frozan in.' By virtue of its greeter size, much more initial energy was released in tho earth, end still more may have been raleesed when the earth's dense fron core formed. This energy was apparently sufficient to keap the earth a wall-stirrad ceuldron for e bililon yeare or more. It will be of considerable interest to determine it this theory of the size dependence of planatory history holds for Mars, Venus, and Mercury. The abundance of wetar may elso be important, as the moon is davoid of weler, in contrast to the earth.

Some Petrologic inferences

Ona of the most interesting findings that has come from the Sm-Nd studies is that the ENd values of young oceanic beselfs correlate very wall with the initial 87 Sr/86 Sr ratios (Figure 9). Although this correlation is not well understood yal, it is clearly a fundamantal datum for all futura modals of aerth evolution. Broadly speaking, it indicates that shifts in Sm/Nd in the earth's mantle are uniformly associated with complementary shilts in Rb/Sr. This simple observation has, in lact, pavad tha way for earth modals of the type discussod abova becausa it damonstrales a consistency and coheranca batween tha behavior of elemants that differ aubstantially in their gaochamical properties. Its importance can be appraciated if one considers that prior to the Sm-Nd maasuremants, tha existing data, from Rb-Sr and U-Th-Pb maasurements, showed no relationship whatsoavor, which mada attempta lo craata any unifiad modals axtramaly diffi-

Of mora diract petrologic Importance is the striking diverganca of Island arc Frid values from the ganaral frend definad by all other ocaanic lavas. The shift toward higher ⁹⁷Sr/⁶⁵Śr is due to tha iniluance of ocaen watar in tha tormation of thesa rocks. Ocean water contains substantial

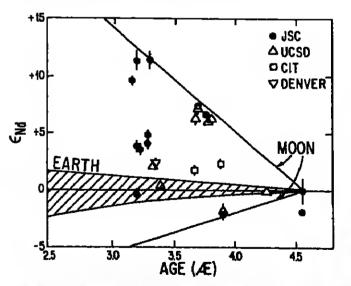


Fig. 8. PM values for lunar basalts (compare Figure 4). The large ecetier indicates that the tunar mantle became highly chamically halerogenaous within the first few hundred million years atter the moon formed. The earth's mantle, in contrast, was highly homoganeous for almost half of the aerth's history. (Data from a aummary by Nyquist et al. [1979]).

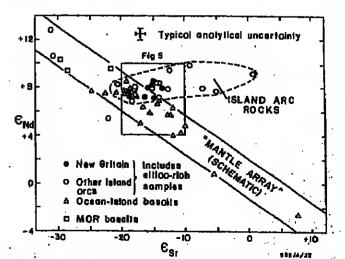


Fig. 9. Corralation of and and ar8r/esSr (expressed here as as) for most oceanic baselts is shown as the zone labeled Manile Array, Island are volcanic rocks deviate markedly from this trend [DePaolo and Johnson, 1979].

amounts of Sr with high 67Sr/86Sr, but elnce it contains venlahingly email emounts of Nd. Ittere is no effect on ϵ_{Nd} . The only known meterial that has eleveled ⁸⁷Sr/⁸⁶Sr in relation to ϵ_{Nd} is oceen iloor baselt thei has exchanged Sr with the hesied oceen water which droutales through tractures in the solidilied baselt at midocean ridges, driven by the heat of shellow magme bodies. The divergence of Island arc ϵ_{Nd} values from the main trend haa, therefore, been interpreted as evidence that the magmes that have erupted from latend src volcanos have been generaled from the melting of ocean floor baselt that is descending into the mantie slong aubduction zones beneath the volcanos. This model for the origin of Island are magmes had been proposed much earlier, but these deta represent one of the law good tests of the hypothesis. The inaensitivity of Nd isotopea to hydrothermel alteration elso meke them useful for studying the isotopic composition of older perts of the ocean floor where unsitared baealt hes been difficult to tind.

Geochronology-Sensu Stricto

An additional leature of the Sm-Nd isotope system is that it can be used to determine the age of certain types of rocks that hove been difficult to dete by other methods. Furthermore, the Sm-Nd ages are resistant to mild metamorphism, which can obscure the true ages of rocks by disturbing the systematic isotopic relationships that yield the ege information.

A rock type that has been perticularly problematical is besalt and ite coarser-greined equivalent, gabbro, eapecielly those of great age. As noted above, thase rocks are importani because they are aampiers of the manile laotopic ratios. Also, they are often valueblo for paleomagnetic atudlos. An exampla of an ege determinetion on an encient gnbbro whore Sm Nd Ia ussd Ia ahown in Figure 10. in this caao a precise Sm·Nd Isochron ego was obtained, whereas only crude ages could be obtelned by Rb-Sr. Similer recuile were obtained by Homilton at al. [1977], who deted a number of Archeen volcanic terranes by Sm-Nd. The high precielon of the defermined ege demonetrates thet it is poseible to obtain ege resolution in very old rocks that is comparable to the resolution obtained for Phenerozoic rocks. Delailed knowledge of ege relationships batween different rock units, which will be necessary in order to compare the Ilme scalos and aequences of geologic processes et present with those of 2 to 3 eons ago, is therefore eccessible by combining the Sm-Nd mothod with other methods that mey be more aensilive for other rock types. Application of these precise deling techniques in consort with geologic sludies of Precambrien Ierranes hea yet to be underteken. The Sm-Nd eystem also offers e meens of better determining the synchronelly of volcanic units used in peleomagnetism for pale positions.

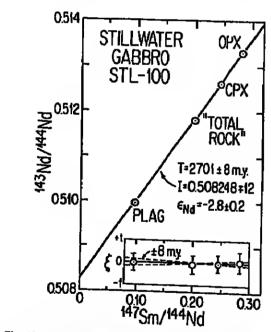


Fig. 10. Sm-Nd mineral Isochron for e gebbro from the Stillweter Intrusion, southwestern Montane. By combining Sm-Nd dating with other methods, egg resolution of \pm 10 million years mey be obtainable on most rock types throughout the 3.6 eon geologic record. [Figure from DePaolo and Wesserburg, 1979b].

Oceanographio Applications

An interesting application of Nd isotopic studies hee recently been reported by Piepgras et al. [1879]. They meesured EN velues in oceen water and ferromangenese nodules from different oceans. The reaults, seen in Figure t1, show theil each ocean hes a different but characteristic range of FM. The values messured do not represent detriled malerial but, relher, correspond to the values of Nd diasolved in the oceans. The values for the different oceans represent differences in Isotopic composition of the Nd being carried into the oceans from the continents by rivers, coupled with a short residence time for Nd in seawater. The variability of the Find in water coming from continents is due to differences in the egea of the continental rocks (see Figure 5). For exemple, the regions that drain into the Atlantic are underisin by very old rocks, which consequently have large negetive values of s_{Nd}. On the other hand, the Pacific is ringed by young regions of the continental crust that have less negetive ϵ_{Nd} values. These differences are preserved because the Nd entering the oceans precipitates out onto the aealloor too quickly to allow interocean circulation to hamogenize the isotopic composition between oceans. The gross difference in and values between the ocean masses and oceanic rocks clearly suggests that the

Fig. 11. z_{Nd} values measured in ocean water and terromanganese nodules from different oceans (from *Plapgres et al.*, 1979)

bulk of the dissolved rere earths in the oceans is derived from continents. These preliminary studies show that Nd leotopic studies of oceans may be useful for the study of interocean mixing rates and the currents responsible for auch mixing. The dats also reveal a curious frony: the $\epsilon_{\rm Nd}$ of different oceans are drastically different, while $\epsilon_{\rm Nd}$ in the manile beneath the oceans is virtually identical for all oceanal Apperently, for Nd isotopes the mantle is a more well-mixed system than the oceans.

Heterodoxy

Sm-Nd isotope atudies are now limity entrenched as a tool of tiret magnitude importance for the unreveiling of pfanetary hisfories. Thay will no doubt play a leading role in the charecterization of evolutionary time scales for Mars, Venus, and Mercury if (or whan) rock asmples from those planete are returned to earth. But in conclusion, it may be prudent to ralea an issue that has been glossed over in this presentation but atili remains an important problem.

Having died the correspondence between the Sm/Nd ratio of the earth and that of chondrites as a central strangth of the Sm-Nd isotopic investigations, it is an adilying exerclse to entertein the possibility that the Sm/Nd ratio of the earth is in tect different from thet of chondrites by e small but significant emount. This issue has recently been called to ettention by a revision of the Chur evolution curve that resulted from e set of precise measurements of meteoritee by Jacobsen end Wassarburg [1980] at Celtach. Possible ressona for such a herelicel circumstence include the fact that (a) small but significent Sm/Nd trectionation occurred during condensation or (b) chondrites do not precisely correspond to the composition of the earth for rare-earth elements. Theoretical calculations auggest that the former el-ternetive is possible but not likely [Boynton, 1975]. The istter elternstive la e lundamentel geochemicel question. If it could be proved true, the remifications would be ler-reaching, but et preaent there is no substantiel indication that it is. Furthermore, the correspondence between the solar and chondritic Sm/Nd, end the present underetending of rereaerth behavior during condensetion, suggest that it is an unlikely circumatance. A third posability, aomewhet more difficult to discount, is that a shift of the earth's Sm/Nd occurred ea e consequence of formetion of the moon by tission from the eerth (Figure 12). Fission (or elternetive but anelogous procesaes) has been discuseed more or less seriously for a long time [cf. Ringwood, 1875]. Il such a process dld occur, it is possible that the moon took with it more or less Sm or Nd then the chondritic proportions, leaving the earth with e perceptibly shifted Sm/Nd in relellon to the chondrita everage. It has in lect bean suggested by Lewrence Nyquiet and coworkars at the Johnson Space Center that the Sm/Nd of the moon is lower than chondritic [Nyquis et al., 1977]. If the eerth's Sm/Nd were higher than chondritic by 5%-7%, it would, emong other thinge, remove the necessity of a leyered mantie es diegremed in Figure 7. However, it would make the $\epsilon_{Nd} = 0$ clustering of the continental flood bassite even more puzzling. These and other implications of a fleaton origin for the moon will have to be reckoned with In future Sm-Nd studies, elthough the burden of proof must fall to proponents of this theory, for the foreseaable future. To return to the original aeaertion, it ahould be noted that no substentiel evidence presently exists to suggest That the earth's Sm/Nd is anything other than preclassly thei of the average chondrite.

The next decade will most probably see the Sm-Nd deta base increese enormously as more laboratorias begin to make measurementa. With these data and an anhanced information axchange with scientista of other disciplines, there is resson to expect that the understanding of earth avolution will mature considerably. A word of caution

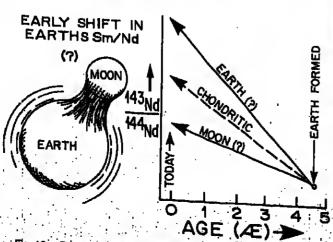


Fig. 12. Possible No isotopic effects caused by fission of the moon from the earth.

is elso in order, however, ee Nd leotopic measurements tequire e precision and eccurecy that is at the limits of the capabilities of the best current instrumentation. It is, in fact the necessity that prevented implementation of the method until the 1970's, when e new generation of mass speciremeters emerged [Wassarburg at al., 1969]. A proper combination of precise measurements and careful consideration of the dats will be naceseary. Thus fer, too few labs heve sufficiently demonstrated the eccuracy of their determinetions of 143Nd/144Nd and Sm/Nd retios. This fact, and the lack of interisboretory comparisons vie well-characterized standards, can leave even an expert et a loss when attempting to eveluate and compare deta.

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Donald J. DePeolo la an essietant professor of geology and geochemistry at the University of Celtfornis, Loe Angeles. He holds a B.S. trom the Stete University of New York at Binghamion and a Ph.D. in geology from the Celtfornie Institute of Technology. His research has centered on probleme associated with the evolution of the earth's mentie and crust, the origins of igneous rocks, and the thermodynemics of magmes.

News

Winter Snow Drought

The wintar of 1980—81 can be beet described as e 'snow drought.' Doneid R. Wiesnet and Michael Metson of NOAA's National Eerth Satelille Service, who have been monitoring snow cover by using setelille measurements, report that the December—Februery snow cover in North America sveraged only 13.9 million square kilometers, which is four attanderd devictions below the 10-year meen (15.5 million km²). Jenuary 1981 enow cover (14.1 million km²) was the ell-time lowest Jenuary since the setellita records began (1968). February, with only 14.2 million km², was the lowest February of record. As a result, Wiesnet and Malson are estimeting that the Decamber—Merch total will also be the lowest of record.

Figures for Eurásia are also below average, but not es dremstically as those of North America. When edded together, snow cover on both continents isnd messes to the lowest (40.8 million km²) it has been since 1970.

Many regions are dependent on snowmelt to suetain their water supplies throughout the year. Although the drought in the northeaetern U.S. has abated in recent weeks because of rainfell, other areas dependent on snowmelt runoff will be forced to plen for a reduced seasonal empty.

This item was submitted by Don Wiesnat, who is a member of AGU'a Snow and Ice Commission.

Ocean Objectives for the '80's

Seven gosls and objectives for services to ocsen operationa in the coming decede are outlined in a recent report by a task group of the Netional Advisory Committee on Oceans and Atmospheree (NACOA). The group elso identified the principal driving forces expected to influence ocean

NACOA (Eos, Februery 24, p. 76) advises the President on ocean end etmoepheric affeira. The Tesk Group on Servicee to Ocean Operations, chaired by Robert M. White at the University Corporation for Atmoepheric Research, is one of elx task forcea established by NACOA to Identify gosle for ocean activities. The task group's recent report locusee solely on civilian programs.

The 'principal enginea of change' eingled out in the report are projected new ocean usas, shifting populetion growth to coasts, anergy, fisheries, end science and technology. Among these are ocean thermal energy conversion (OTEC) and noxious waste disposal. These usas raise the need for essessment of possible environmental effects, the tesk group said. The big pushea for ocean use trom science end technology, according to the report, come from setellite platforms, remote aensing, computer data banks, improved seabed geology studies, and ocean current atudies. Also included in this category are advances in the National Climata Program, with implications for trensportation, agriculture, and recreation.

In fight oil these driving forces, the task group outlined

seven goals and objectives:

• Ocean observation end prediction: To implement a new ocean observation aystem by deploying edvanced technology and by using the new information to predict in teal time the etate of the oceanic environment.

Nevigation and positioning: To realize an ell-weather worldwide navigation system of high precision for resource exploration and development and for vessel traffic control.

 Mepping and charting: To improve the productivity, coverage, and responsiveness of present ocean mapping and charling programs.

• Ocean dele and information dissamination: To establish e tast reeponee, tachnologically advanced, ocean environmental data archival and diagemination system to meet user needs.

• Monitoring the oceen: To deelgn and implement e system for monitoring and aseeeeing oceanic water quality and other parameters that affect ocean life and that are required for fishery and pollution management.

National ocean measurement capability: To eatablish new messurement cepabilities, including the devalopment of eubmersible manned and unmenned veasels.

ensure the proviolen of ocean and atmospheric information: To source necessary for support in the polar regions.

Some of the task group's recommendations are not pos-

Some of the task group's recommendations are not possible in Precident Reagan's proposed (lecal 1982 budget, however. For example, the first goal calls for development of a national ocean aatellite program. Reegan cut the National Oceanic Satellite System (NOSS) from the budget (Eos, March 24, p. 123). In addition, the goal of ocean date and information dissemination requires the eateblishment of information ayetems to the into coastal zone management and eea grant programs; both of these programs have been aliminated from NOAA's budget.

But the task group asserted that it takes a long-term view of neede and recognize at that 'ahort-term fiscel constraints may require adjustments in the recommanded program planning."

Members of the teak group are chairman White; D. James Baker, Jr., University of Washington; Wemar A. Beum, Florida State University; William A. Radlinaki, Amarican Congress on Surveying and Mapping; Owen W. Siler, Mentech International Corp.; Atheletan F. Spilhaua, University of Southern California; Sharron L. Stewart, Texas Deep Water Port Authority; Verner E. Suomi, University of Wieconein; T. K. Tresdwell, Texas A&M University; Don Waleh, University of Southern California; Warren M. Washington, National Center for Atmospheric Research; Elmer P. Whealon, ocean technology consultant.—BTR 38

Lightning Superbolta

A rare type of lightning bolt previously not thought to occur in fletlands has been identified in Oklehoma preirie storms and could pose a denger to structures not built to withstand it. Researchere et NOAA say the discovery could indicate thet buildings or power plants designed on the assumption that such destructive bolts do not occur in fletlend might not be sate. The positive charge cloud-to-ground flashes once were thought to atrike only when triggered by a tall structure or mountaintop, or, on rere occasions, et the end of s atorm.

'Most atorms never produce this kind of lightning. In a few storms, there may be one positive bolt, just as the storm is dissipeting—sort of the last gasp of the storm,' according to Devid Rust of the Netional Severe Storms Laboratory. Rust added that the triggered bolts often are very high current, making them especially destructive. 'We know these bolts don't occur in garden variety storms. We are trying to find it the occurrence of this kind of lightning le linked with eterm severity,' Rust said.—PMR 56.

Decline in Tornado Death Rete Faces Test

Although records show a 3-year decline in tomsdo-releted deaths, the trend could reverse between now end May, the peek tornado month. Therefore, NOAA end the Federel Emergency Menegement Administration (FEMA) ere urging that the public be prepered to take the eppropriate aatety measures. It is vital that people not relax their vigilance against these dastructive storms, Richard E. Haligren, director of the National Weather Service (NWS) seld. If they do, we could wilness en unwarrented number of caeual-ties.

Leat year's 28 tornedo-releted deaths were the second lowest since records have been kept. There were 53 tatalities in 1978 end 84 in 1979. The 30-yeer average is titt. 'The low tornedo death rate lest year cen be attributed, in part, to the occurrence of only five major killer tornados, comperad to about 20 for en averege year,' said Fred Ostby of NOAA.

'Other contributing tactors include the tornedo watch and werning programs, local spotter groups, and the tornedo preperednees ectivities of the Federel Emergency Menagement Administration,' he edded.

The most deedly 1980 tornsdos occurred at Grand Island, Neb., on June 3, when seven struck, killing live people and ceusing en estimated \$300 million in demage. Mejor storms also hil in Kansas, lowe, Indiana, and Pennsylvania isst year. Kensas, Missouri, end Okishome had tewer then normel because of drought end excessive heet.

Statistics on numbers of tornedos and the resultant deathe can be traced back to 1916. Since that date and through the 1980 tornedo sesson, there were 25,968 tornedos throughout the United States, resulting in 11,301 deaths. The increasing numbers of tornados, listed by decade in the table, are not due to more occurrences but reliect better reporting procedures.—PMB

Decade	Tornedos	Deeths	Tolsi Property Losses
1916-1919	355	1,043	6.7*
1920-1929	1,325	1,169†	8.8
1930'a	1,685	1,945	8.6
1940's	1,554	1,788	6.9
1950's	4,793	1,409	7.2
1960'e	6,818	834	7.5
1970'a	8,575	887	8.5
1980 year total	884	28	-
	Annual A	veragss	
19181980	406	177	
1880-1980	613	87	
(20 year)			
1950-1980	702	112	_
(30 year)			

*Storm demage by cstegory: 5—\$40,000 to \$500,000; 6—\$500,000 to \$5 million; 7—\$5 million to \$50 million; 8—\$50 million to \$500 million; 9—\$500 million and over.

†Includes most deadly tomado on record: March 18, 1925. This tomado killed 899 people, while sweeping e 220-mile path through southern Missouri, Illinois, and Indians. &

Gamma Ray Observatory Survives

Right now the budgetary position of NASA aclance projecta for liscal year 1982 is shaky, outside of the Space Shuttle Program. Two sciantifically cruciel miselons being planned are the Gamma Ray Observatory (GRO) and the Venue Orbiting Imaging Radsr (VOIR). President Resgan's proposed budgetery cuts have left both programs intact but delayed. For FY 1992, GRO will be able to continue at only 15% level—'about anough money to keep the papers ehuffling,' according to a NASA official (Science News, Mar. 14, 1981). Nonetheless, the importance of pisnning the GRO mission, now scheduled for a launch date in 1898, has prompted the selection of instruments as follows:

Translant event monitor—which will dated the short, intensa bureta of gamma reys of currently unknown origin and localize them with sufficient accuracy to detarmine their distribution in the galaxy.

High-energy gamma rey talescope—which will measure the energy apectrum and arrival directions of the highest-anergy gamma rays that can be observed.

imaging Complon teleacope—which will provide gamme ray maps of the celastial sphere at medium energies.

Low-shergy gamme rey spectrometer—which will search the lowsst-energy gemma raya for spectral features, such as avidence of nucleoaynthaels in supernovee.

Studias of gamma ray sources and gamma ray produc-

(

tion ere at the very heert of understanding the dynamics end evolution of stars, gelexies, end the universe. Gemma reys are produced in the most powerful processes in the universe, and their high energies qualily them ee the most direct probe we heve of these processes. The gemma reye measured by the GRO begin at about 100,000-eV (100-keV) energy and continue up to severel hundred million

electron volta energy (100 MeV, or more).

Principal invealigetore for the tour instrumente are Geratd
J. Fishman, Marehall Spece Flight Center, Hunisville, Ale.,
lor the trensient event monitor; James D. Kurfeas, Nevel
Research Leboretory, Washington, D.C., tor the low-energy
detector; Cerl Fichtel, Goddard Spece Flight Center,
Greenbelt, Md., Robert Holstadter, Stanford University, end
Klaus Pinkau, Max-Plenck-Inetitute, Munich, for the highenergy telescope; V. Schoentelder, Max-Planck Institute,
Munich, John A. Lockwood, University of New Hempshire,
B. N. Swanenburg, University of Leiden, the Netherlands,
end B. G. Teylor, Space Science Depertment of European
Space Agency, The Netherlands, for the medium-energy
Compton telescope.

The predecessor apacecrst to the Gemme Rey Observetory are the High-Energy Astronomy Observatory 3, which looked et high-energy x reya and low-energy gamme reys, end the Smell Astronomy Salellite 2 end the COS-B (a Europeen eateltite), which looked et high-energy gemma reye.

The Gemma Ray Observelory will be pisced into a 400 km high, 28.5° inclined circuler orbit. It is expected to provide information on gamma raya for 2 years. It will be one of the largest observatory estellites ever pieced in orbit, weighing about 10,432 kg end measuring 7.6 m long and 3.8 m in dismeter.—PMB 56.

Columbia's First Shakedown Flight

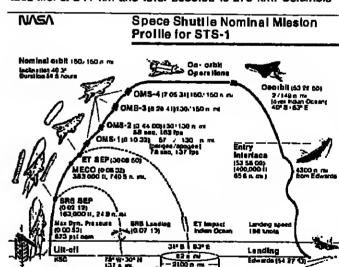
The spece shullle orbiter *Columbie*, lirst of the planned fleet of spececreft in the netion's spece frensportetion system, will liftoff on its that orbital ehekedown tilght on or ebout the 10th of April 1981. Launch will be from the NASA Kennedy Spece Center Leunch Complex 39A, no earlier then 45 minutes after sunrise. Crew for the lirst orbital flight will be John W. Young, commender, veteran of two Gentiniand two Apollo space flights, end U.S. Nevy Capt. Robert L. Crippen, pilot. Crippen hes not flown in space.

Columbia will have no peyloads in the peyload bay on this lirst orbitel llight, but it will carry instrumentation for measuring orbiter systems performence in space and during its gilde through the elmosphere to a lending after 54% hours.

Extensive testing of orbiter systems, including the spece redictors and other heat rejection systems, tills most of the STS-1 mission timeline. The clemshell-like doors on Columbia's 4.6 by 18-m peyloed bey will be opened and closed lwice during the tilight for lesting door ecluetors end letch mechanisms in the space environment.

Other teata will meesure performence of meneuvering end etilitude thrusters, the *Columbie's* computer array and evionics 'black boxes,' end, during entry, silice-file heat shield temperatures.

The tirst of tour engineering test litights, STS-1 (see ligure) will be launched into e 40.3° inclination orbit circuler-lized lirst et 241 km and leter boosted to 278 km. *Columbi*e



will be used in these four test flighte in proving the combined booster and orbiter combination before the Spece Transportetion System becomes operational with STS-5, now ferecast for launch in September 1882.

After 'tower clear' the launch learn in the Kennedy Space Center liring room will hand over STS-1 control to flight controllere in the Mission Control Center, Houston, for the remainder of the flight.

Columbia's two orbital meneuvering syefem hypergolic engines will fire si approximately 53½ hours over the indien Ocaan to bring the spececraft to a landing on Rogers Dry Lake af Edwards Air Force Base, Callf., an hour leter. The approach to landing will orose the Cslifornia coast near Big Sur si 42,870-m aliliude, pass over Bekerefield and Mojeve, and end with a sweeping 225° left turn onfo final epproach.

Young end Crippen will land Columbie manually on this first teat flight. A microwave landing system on the ground will be the primary landing aid in aubacquent flights, with optional manual takeover. Kennedy landing teems will remove the flight orew end 'eele' the orbiter after landing.

The first three teat flights land on Rogere Dry Leke, the lourth on the main runway et Edwarde Air Force Bese, and STS-5 will land on the 4570-m concrete abuttle landing lacility runway et Kennedy Spece Center.

STS-1 will be the first manned flight using solid rocket boosters. Note that no previous U.S. apace vehicle has been manned on its malden flight. [Meterist from NASA]—

(News conf. on page 142)

(Naws cont. from page 141)



Volcanio Violence Varies Vista

This recent photograph shows Mount St. Helans' crater about a your affer the volcano came to life on March 27, 1980, following 123 years of quiet. The lava dome (the darkened, raised eras in the photo's centor) doveloped during the volcano's eruptions over the last sevaral months. The doma now measures

150 m In height and is 810 m long. The upper part of the photo shows the steep walle of the 2-km by 3.2-km crater. Currently, the creter occupies the general area of the north fece of the mountain, which bulged for months prior to the violent May 18 eruption, (Photo courtesy of the U.S. Geological Survey, Department of the interior) &

Geophysicista

James Andrews, marine geologist and geophysicist, has assumed fine position of director of the Ocean Science and Technology Laboratory of the Navaf Ocean Research and Devalopment Activity (NORDA).

Geophysical Events

This item comprises selected reprints from the SEAN Bulletin, 6 (2), dated Feb. 28, 1981 [with data included through Mar. 10]. SEAN Bulletin is a publication of the Smitheonian Institution.

Volcanic Activity

Mount St. Hetens Volcano, Cesceda Range, southern Washington, USA (46.20°N, f22.18°W). All limes are local (GMT - 8 h). Mount St. Hetens remeined quiet as of March 10, as it has since the end of the lava extrusion spisode of Februery 5-7. The Februery lave approximately doublad the volume of the composite dome in the crater, adding about 5 × 10° m³ of new material to the 1.5 × 10° m³ extruded October 18-19 and the 3.5 × 10° m³ extruded December 27-January 4. All of the preexisting dome, except for a portion of the December-January southeast lobe, was covered by the Februery lava. Between February 8 and 21, the Februery lobe epread 12 m while sagging 3 m, resulting in dimensions for the new lave of 281 m in E-Widnertion and 119 m in maximum height ebove the creter

Low-trequency volcanic eerthquakes essociated with the February lave extrusion ended February 9. Occasional bursts of seismicity continued to be recorded. One such burst, on February 10 at 0915, coincided with the emission of a cloud of steam, containing a minor amount of ash, that rose to 4-km eltitude. Field crewe reported hearing e boom prior to this event. Some rock avalenche events were elso recorded efter dome emplacement anded. A magnifude 5.5 tectonic earthquake occurred fate February 13 (eerly February 14) GMT; aee earthquake table, p. 144) about 12 km north of Mount St. Halens. As of February 28, about 175 ettershocks greater than magnitude 1 had been recorded. Through the end of February, selemographe continued to record a few rock avalanche events and bursts of seismices deen aesociated with staam explosions. Clouds prevented observations of the creter for much of February, but clear weether on the 28th rovealed avidence of numerous minor efeam exploalons on the north side of the lave dome.

Geodetic measurements ahowed a few centimeters of horfzontal contrection of the Mounf St. Helens addice between Februery 4 and March 5. No significant movement of the northern crater rampart occurred efter the early Februery doma emplacament, nor has there been any measurable deformation of the creter floor during this period.

The following, from W. G. Melson, le based on microprobe enalysee performed on the 1980-1981 Mount St. Ifelens eruptives.

The SiO₂ content of assential ejecta from Mt. St. Helens underwent a elight increase in the 7 August eruption, which peaked in the 17–19 October eruption but remained lower than for the t8 May taphra. This temporarily reversed a prior trend toward more besic compositions, which resumed with the December-January and February doma enlargements. CaO, FeO, and MgO show an inverse relationship to SiO₂ (Figure 1), an expected relationship in e 'normat' fractionation sequence.

Information contacts: Don Swanson end Chris Newhall, U.S. Geological Survey Field Office, 301 E. McLaughlin, Vancouver, Washington 98683.

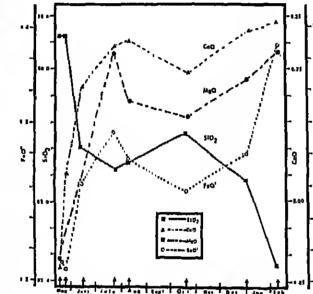


Fig. 1. Chenge of SiO₂, CeO, FeO, end MgO as a function of time of eruption. The enalyses are by electron microprobe analyses of fused powders, performed at the Smithsonian institution, Division of Petrology and Voicanology, by W. G. Melson, J. Nelen, and T. O'Heern. Each analysis to the everage of the following number of individual enalyses of escential ejects: May 18, 9; May 25, 11; Juna 12, 9; July 22, 7; Aug. 7, 10; Oct. 17–18, 11; Dec.—Jan. dome antargement, 8, Feb. dome enlargement, 1 (eample from D. A. Swanson, U.S. Geological Survey). Anelytical precision for each enalysis is about a 2 σ of: SiO₂ = 0.62, FeO' (all Fa ee FeO) = 0.43, MgO = 0.33, CeO = 0.17.

Christina Boyko, Stevan Malone, Elliot Endo, and Craig Weaver, Graduefe Program in Geophysice, University of Washington, Seattle, Washington 98195.

Robert Tilling, U.S. Geologicel Survey, Stop 906, National Center, Reston, Virginia 22092.

W. G. Maison, Division of Petrotogy and Voicanology, National Museum of Natural Hietory, Smithsonian Institution, Washington, D.C. 20560.

Piton de le Fournaisa Volcano, Réunion Island, Indian Ocean (21.23°S, 55.7 t°E). Aff times ere local (GMT + 4 h). A fiseure eruption etarted February 3 on the north side of the updomed aummit region thet surrounds Bory and Dolomieu craters (see Figure 2). Leva extrusion trom this erea

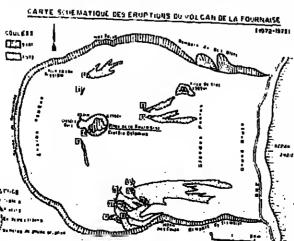


Fig. 2. Mep of the calcera of Pfton de la Fournelse (from Kraffi, M., and Gerenta, A., L'activité de Pilon de la Fournalea entre Octobre 1972 et msi 1973, C. R. Acad. Sci. Paris, Ser. D., 284, 607—610, 1977).

continued until February 25. Attar about 13 hours of selsmicity, fisaures opaned on the southwast side of the summit aree end began to eject lava. The eruption was continuing as of March 3.

Activity north of the eummit, Fabruary 6–25: During the first few days of the eruption, levs was axtruded from e series of radial fleauree in the northern summit region. By February 6, lava founteining was confined to a spatter cone at 2350-m attitude at the lower and of a fissure that opened February 4. Lava flows amerged from one or two vents about 300-m downslope from the active apatter cone and moved about 1.3 km to the east (see Figure 2). Founteining was most intense February 10 (30 m high) and February 18 (100 m high). About Fabruary 19, a small lave lake formed inside the active cone. Lava fountains rose a few meters above the lake surface. A 2-m-diameter vant high on the cone emitted blue and yellow flames 3–4 m high. The spatter cone pertially collepsed February 20. Lava overflowing the collapsed area formed a front 100 m wids.

Founteining and extrusion of lava flows began a rapid decline on February 23 and stopped on the 25th. Several million cubic maters of lave were extruded during the activity February 3–25.

Activity aouthwest of the summit, beginning Februsry 26: Seismographs al Réunion's voiceno observatory began to record a eeries of small (about magnitude 1) local earthquekes around midnight on the night of February 25-28. Earthquakes becema increesingly frequent thet morning and by 1230 were occurring once every 15 s under the eummit'e Bory Cretar. Hermonic tremor etarted at 1300, and the beginning of eruptive ectivity was observed at 1306. Two minutes leter, a large black cloud rose to 2 km height. Two en-echaion radiel fissures, trending N74°E, opened on the southwest alde of the updomed summit region. The upper fleaure, 200-300 m long, extended from 2400-m to 2250-m altitude. The lower flasure, offset about 100 m from the base of the upper fiseure, extended about 100 m farther downslope. Lava fountains rose to 15-m height from the entire tength of the upper flasure, while fountaina from the lower flasure were 50-60 m high. After half on hour, lava from the two fissures had merged into s aingle aa flow 2 km long that apread onto the caldera floor and moved towerd the south caldera wall (Figure 2), Midalternoon outflow retea from the two flesurea were about 300 m^3/s (about 1 × 10⁸ m^3/h), much higher than at any time during the northern aummit region activity earlier in the month. The leva wes an aphyric basalt, es was the February 3-25 material. By about 1800, lave lountaining elong the upper flaaure was concentrated at its lower end, where e cone was growing. Salsmicity ended within a few hours of the etert of eruptive activity on Februery 26, a pattern similar to that observed of the beginning of the eruption

Februery 3.
Lave lountaining elong the entire lower fissure continued until 0200 on Februery 27, then was limited to the middle of this liasure, where a cong formed. The rete of lave outflow declined to 80 m³/e by the morning of the 27th end 10 m³/s the following day. Fountaining from the upper lissure stopped February 28 but continued from the lower lissure, building e 15-m-high epatter cone. Two other epatter cones formed elong the lower fiesure March 1, with activity concentreting et one of these, elao ebout 15 m high, on March 2. The rate of lava production remained at about 10 m³/s as of March 2, leeding a alow-moving leve llow that was incandsscent for the upper 1,5 km of its length.

Information contecte: Meurice Krafft, Equipa Volcain, 8.P. 5, 88700 Cemay, France.
L. Stieitjes, BRGM, Service Geologique Regional, B.P.

1206, 97484 Saint Denis, Réunion.
Voicano Observatory di Réunion, c/o Inatiliut de Phyaique
du Globe, Tour 14, Univereité de Paris VI, Piaca Jussieu.

Krafia Caldara, Mývatn Area, icelend (65.71°N, 16.75°W). Aff times are GMT. The following is a report from Karl Grönvold and Páll Einersson.

75230 Paris Cedex 05, France.

An eruption attarted in the Krafia flesure swarm shortly efter 1400 on 30 Jenuery. The early end main parts of the eruption ere described in last month's Bulletin. The initial vigorous phase lasted from the first day

until the early morning of 31 January. Then activity began to decrease, with shortening of the creter row, which initially extended 2 km and then decreasing activity in the creters end declining lave production.

The final activity in the craters died out just efter 1400 on 4 February. During the eruption, slow deflation over the Krefle magme reservoira, 8–9 km to the S, was observed, but infletion etartad agein at about the seme time as the eruption ceased. Tha lava covered 8.3 km² and appeared to be similer in volume to

the fwo previous aruptione in July end October 1980. Considerable movement of faults extending ebout 1 km N of the main lave (ebout 8 km N of the craters) was observed. Large volumes of steam emitted from these faults suggest that lave again forced its way down into the feults and then northward. Renewed earthquake activity in this region on 1 February was possibly associated with this fault movement.

By early March the infletion of the magma reservoirs had regeined over half of the deflation that eccompanied the eruption. Experience indicates that previous ground levels will be reached about the end of March to early April.

information contacts: Kart Gronvöld, Nordic Volcandoglcel Institute, University of Iceland, Reykjevik, Iceland, Páli Einerseon, Science Institute, University of Iceland, Reykjavík, Iceland.

Etna Volcano, Sicilly, Italy (37.73°N, 15.00°E). The latitute internazionale di Vulcanologia reports explosiona and extrusion of lave from Etna's northeast oreter. After e psilon of esh emission at the end of January and the beginning

of Februery, stronger ectivity began with Intense explosione the evening of Februery 5. Lava flowed through e breech in the west-to-northweat sida of the northeast crater cone. It formed three lobes that moved west, northwest, and north and covered the uppar northwaet slope of the voiceno. The northern lobe, the largeet, traveled ebout 2 km to about 2800-m elavetion, where it had a 1.2-km front. The eruptive activity atopped the evening of February 7.

Eruptiona occurred at the northeast cretar in 1975 and 1977-1978. Explosione end axtrusion of lava were most recently observed there in September 1980.

Informetion contacta: Romolo Romano, latituto internazionale di Vuicanologia, Viale Regine Margherita, 8, 95123 Catania, Italy.

John Guest, University of London Observatory, Mill Hill Park, London NW7 2QS England.

Mt. Erabus Volcano, Rose taland, Antarctica (77.58°S, 167.17°E). The following is a report from Philip Kyle.

The summit crater of Mt. Erebua was visited by Japanese, New Zealand, and U.S. scientists during late December and early January. A 1-day vielt was elso made in November. The anorthoclase phonolits lava lake (tirst observed in 1972) was still present, although its level mey have been slightly lower than that observed over the last 2 years. The 120-m-long ovalabeped lava lake still shows a simple convection pattern with leve apparantly welling up from two centers about a third of the way from each end.

Small etrombollan eruptions conlinued et a frequency of between two and six per day. The noise associated with the eruptions consisted of e long drawnout roar. This contrasted with the strong explosive eruptions heard in previous years. Although no eruptions were witnessed they are believed to occur from the small vent called the Active Vent, which is adjecent to the lava lake, Very few bombs were lound on the main cratsr rim during December, but in January there were a few sharper explosive eruptions and these ejected material onto the rim.

The three nations mentioned above commenced a new project and instelled three permanent seismometars on the mountain. The selamometers have radio-telemetry links with Scott Base (the New Zealand research etetion on Ross Island). Two selamometer stelions are on the W flank of the volcano at altitudes of between 1500 and 1900 m about 5 km from the crater rim. It is anticipated that these stations will run until April, when darknese sets in. The stations should be reactiveted in October, when new balteriee will be installed end the eolar penete will function. The third stelion is at the summit of Mt. Erebus, and hes its batterlea buried in werm ground, if is hoped that it will operate all yeer round. The eummit station is also transmitting the output from an acoustic eensor (a microphone which monitors the sounds of volcanic eruptions) and e lerge wire loop around the creter, which monitors induced currents. A lourth permanent seismic station will be inetalled in December 1981.

Preliminary observations from the seismic network, which can detect events with megnitudes less than 1, indicate a eurprisingly high level of microeerthquake eclivity, with up to 10 evente per day. Some of these are epparently lectonic earthquekes occurring some distance from Mt. Erebus. Antarctica has been considered assiemic, but this is epparently not the case, et least not for microearthquakes with magnitudes less than 3.

Information contact: Philip R. Kyle, Institute of Polar Studies, Ohio Stele University, Columbus, Ohio 43210.

Merapi Voicano, Java, Indonesta (7.54°S, 110.44°E). The lava dome that began to emerge at the summit of Merapi in 1979 was atill growing in February and had reached an altitude of 2947 m. Leva fragments from the aast and central pert of the cone had moved 2.0 km toward the Beteng River and 250–500 m farther in December. Personnel at the Ngepos Observatory have counted 34 larger and 488 smaller lava avelanchea in recant months. [The time intervat wae not reported.] Nuées erdentes de evelanche occurred in Novamber and December but were confined to the summif arsa of Merapi. Two Minakami A-type earthquakes, the first in severel monthe, were

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800-424-2488. Back cover advertising space available. recently recorded by the ssismograph at the Babadan Obsarvatory. No important lahars have occurred along the Puth, Bebeng, and Krasak rivers alone the beginning of this year's reiny season.

Information contect: A. Sudradjet, Director, and I. Pardyanto, Sanior Geologist, Voicanotogical Survey of Indoneela, Diponegoro 57, Bandung, Indonesia.

Paluweh (Rokelanda) Voiceno, Lasser Sunda Islands, Indonesia (8.32°S, 121.71°E). Ali times ere local (GMT + 8 h). The Volcanological Survey of Indonesia provided turthat details about the intermittent explosive activity that began on November 5 and continued through the end of January. The 40-m-diameter crater mantioned in last month's Buffetin was formed during one of the early November eruptions and le altuated on the north northeast uppar part of the volcano. Bombs from the 1-km-high eruption column on November 9 measured up to 80 cm in diameter. Beginning January 18, renewed activity was reported. A hot air wave wae felt by the inhabitante of two east flank viitages. About 1850 persons were evacuated from the dangar zone. After the explosions on January 31 a new lava doma was observed in the crater. Activity declined graduelly, and the volcano eppeared to be normal again on February 1 at 1200. No casualties trom Paluwah'a November-January activity were reported.

Information contact: Same as for Merapi.

Semeru Voiceno, Java, Indonesia (8.11°S, 112.92°E). Ash emiesion continued at en averege rete of once every 58 min in November and December. Ash columns typically rose 500–700 m above the crater rim. Some clouds were less ash-rich, as indicated by a grayish color. Incandescent lava fragments were sometimas visible at night, Strombolian-type eruptiona have eccompanied the formation of the lava dome since extrusion begen in 1987.

Lava svalanchea from the dome have usually been contained at about 3-km altitude on the south flank of the volcano in the upper reachea of the Kember Rivar, but ona traveled larther down the river valley in early December. In advence of this yeer's monagon ratha the Volcanological Survey of Indoneale has alerted local authorities to the south and southeast of the danger of lahers along the Kember, Kobokan, Rejall, Sat, and Gildik rivers.

Information contact: Same as for Merepi, Pacsye Voicsno, southern Gualamsie (14.38°N, 90.60°W). Pacaye displayed weak atrombotion activity during a visit by Michigan Tachnological University geologists on February 14. This is the first atrombolian activity observed at Pecaya since 1975. Gas emissions have characterized the activity since late 1977.

Levs was fountaining to 200 m at 10-s to 1-min intervels from two coalesced spatter vents in the center of MacKenney Crater, high on the west northwest flenk. Four subsidiary vents, two north of the spatter vents and two west of them (in the direction of the volcano summit), also ejected lave. New palnoshos lava llows, some of which were moving, had littled the northern half of the creter floor to the rim. The fountaining was interspersed with intense, pulsating gas emission from the spatter vents.

By February 20, when Robert Hodder climbed Pacaya, one leva flow had traveled a quarter of the way (about 200 m) down the north flank of MacKenney Crater cone, over one of the September 1969 flows. Within the creter, cracks and pressure ridges in the lave crust indicated continued lave movement. Strombollan activity was occurring at about 30-min intervete. Petches of sublimate were vielble on the southeast crater wall.

During a second climb on February 28, Hodder observed that as lave had flowed ebout 750 m from the crater rim to the base of MacKenney Creter cone, into the trough between it and the rim of the oldar Pacaya edifice. The level of level in the creter had risen. The two vents observed on February 14 had totally coalesced and had built cones ebout 15 m high. The lava crust assemed solid, but fincandescence showed through surface crecks at night. Strombolian activity occurred about every 20 min. Larga cowdung bombe, hurled as high as 100 m, fell onto the cones and the lava crust. Bomb sjection was sometimes preceded by a puffy ateam cloud at least 300 m high. Sublimate solidly coated the southeast crater wall. Hodder noted that this eruption assemed similar to thet of 1969.

Information contacts: William I. Rose, Jr., T. J. Bornhorst, and Craig Chesner, Department of Gaology end Geologicel Engineering, Michigan Technological University, Houghton, Michigan 49931.

Robert Hodder, Department of Geology, University of Western Ontario, London N6A 5B7, Onlario, Canade.

Santiaguito Dome, western Guatemala (14.76°N, 91.55°W). All times ere local (GMT - 6 h). Three geologiats from Michigan Technological University epsnt February 12 on Santiaguito Dome, a decite complex which has been growing on the southwest flank of Santa Marie Volcano eince 1922. At 1410 an explosion at Callente Vent (at the east end of the dome) sent up e 400-m-high vertical column of fine ash. It was the only explosion in 8 hours' observation, but two increases in the vent's vapor plume indicated additional gas emissions during that time. The vent was more ective lete leef year when other geologists vielfed

Large dust clouds in the early morning suggested that evelanching was continuing down the southeast slope of the dome. Fine ash coating the leaves and the ground was notable in the area northwest of the volcano.

Information confact: William I. Rose, Jr., T. J. Bornhorst; and Craig Chesner, Depertment of Geology and Geological Engineering, Michigen Technological University, Houghton,

Arenet Volcano, western Coste Rica (10,48°N, 84.72°W). The following information is from Jorge Barquero Hamández The vent located at 1450-m altitude at the western end of

noaa atlas 3 THE CENTRAL NORTH ATLANTIC OCEAN BASIN AND CONTINENTAL MARGINS: GEOLOGY, GEOPHYSICS, GEOCHEMISTRY, AND RESOURCES, INCLUDING THE TRANS-ATLANTIC GEOTRAVERSE (TAG) BY PETER A. RONA, NOAA . 22 MAPS MATITUDE 10'N to SO NI . BOTTOM PHOTOGRAPHIC TRAVERSE . SEISMIC PEFRACTION SECTIONS SEISMIC REFLECTION PROTILES . 12 GEOTRAVERSES (BATHYMETRY GRAVITY MAGNETICS) . PHYSICAL AND CHEMICAL PROPERTIES OF CRUST . EXTENSIVE TEFERENCES . BIBLIOGRAPHY This affects is particularly tamply for scientific studies, resource and environmental investigations, smalloor inguivering and penanographic education." Charles L Drake Price \$17 IAdd \$4.25 Oviside U.S.A.J. 102 Pages, 1919/301 1980 OPO Stock No. 003-017-00475-9 SUPERINTENDENT OF DOCUMENTS
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the elliptical aummit crater aree continued to emit block lava and vapor. The lava flow that began to descend the northwest tlank in early Jufy had reached t100 m by November and continued to advance. Two other tlows that had been active in July on the southwast and west flanks had stopped advancing by November. A newer flow, the 34th since nearly continuous extrusion of lava bagan in 1968, descended the west lienk to 1300 m altitude, where it biturcated that lobes moving west and northwest over the channels of older tlows. The front of the wast tobe was at 800-m altitude on November 11, and the other (NW) lobe had reached 1200 m altitude by November 12. A mean velocity of 1.5 km/h was measured on blocks in the central flow channel on the upper west flank.

The vapor emissions observed between August 15 and 20 were a little mora voluminous then normat. They included small quantitias of ash and were eccompanied by rumblings. The constent noise from the violently ascaping gases was occasionally loud enough to be heard in nearby villages. Vegetation on the upper part of the volcano's eastern flank had been burned by the affects of the vapor eruptions. The loss of vegetation had noficeably augmanted fluviel eroeion.

In a seperate communication, Jorge Umaña reports that as of sarly February Arenal continued to emit lava and vapor from the summil area. The gases had a high chlorine content.

Information contacts: Jorge Berquero Hernández, Editor, Boletin de Vulcanología, Escuela de Ciencies Geográficas, Universidad Necional, Heredia, Coata Rica.

Jorge Umaña, Instituto Costarricensa de Etectricided, Depto. de Geología, Apariado #10032, San José, Coste Rica.

Poás Volcano, northweat of San José, Costa Rica (10.18°N, 84.22°W). Att times are local (GMT ~ 6 h). Fumarolic activity confinued at Poás during August and early September. Sulfurous vapors emittad under pressure from the north welf of the doma in the creter lake rose noisify for an elmost continuous column about 200 m high. The take color wes turquoisa green. Tempereturee registered 40°C in the north part of the take, 45°C in the south part near the dome, end 70–90°C in acceeefbla fumarolea on the

On Seplember 11 et 0950 an explosion from the aouthern part of the lake (near the doma) produced a 250-m-high column of lakeweter faden with esh, aand, and small blocks rich in mineralized eulfur. The ejecte feff back info the lake end onto fhe aeefem shore, where they covered an area of 50 m². A landslide fhat originated from tha northwest part of the doma, tha area of the greatest furnerole activity, deposited debris in the fake end changed the morphology of the seetern sector of the crater.

The initial activity were followed by almiliar explosions throughout September and October. Scientiets at the Institute had predicted resumption of phreetic ectivity from the thermal behavior of the lake, which had been elmiliar to the pattern observed before previous auch eruptions. Temperetures declined alightly in October, to 40° C in the northaest part of the leke from 45° C in September, and to 45° C in the southeast eector (near the September explosion alife) from 50° C in Saptember. Temperatures of the acceedible furnaroles on the dome continued to oscillate between 70° and 90° C in Saptember and October.

Information contact: Jorge Barquero Hemandez, Editor. Boletín de Vuicanología, Escuela da Ciencias Geográficas, Universidad Nacional, Haredia, Costa Rica.

Kavachi Volcano, Solomon Islands, southeast Pacific (9.03°S, 167.93°E). All times are local (GMT + 11 h). Submarine ectivity et Kavachi has been observed eince early October. On November 11 at 1215 a Solair flight diverged from ite normal route to obsarve the volcano. Dra. Hughee and Ounkiey of tha Geological Division, Mintetry of Natural Resourcas, report that a dance, nacry verti-

(Naws cont. from page 143)

cal staem jat billowed to approximately 300 m but dissipatad ee lhe plane approechad. Tha aruption slta wes marked by while water, and a stream of muddy, turbid, pale-brown water axlended several kilometers northeest from the volcano. On December 3, Dunkley obsarved an arae of discolored water severel hundrad metere wide extanding northwaet (down current) about 4 km. No aruption was in pro-

Kevechfe last aruption in June-July 1978 produced a emelf, aphemarai Islend, its eighth island-forming arupflon

information contect: Deni Tuni, Gaological Division, Ministry of Netural Resources, Honlara, Sofomon Islande.

Sekurazima Volcano, Kyushu, Japan (31.58°N. 130.65°E). After en activa month in Jenuery, when 18 explosions from Sekurezima were recorded, only live explosions ware detacted in Fabruery (sea teble). Tha highast Februery osh cloud rose 1.2 km on the 21st. The Februery axplosions caused no demege.

explosione s	u Sak	mis ern	ıa, Fe	bruary	1881	
Dete	6	9	17	22	28	Total
Numbar of explosions:	1	1	1	1	t	5

Information contect: Saismological Division, Japen Melaorologicel Agancy, 1-3-4 Otamechi, Chiyods-ku, Tokyo 100,

Terumai Voiceno, Hokkaido, Japan (42.68°N, 141.39°E). In Februery, 1121 selemic evonis were recorded et Terumal (eoe Figure 3), the most in any month since 1987, when the Japan Meteorological Agoncy bagen roulino moesuremants of the voiceno. Salsmicity has irragularly but gredually increseed in the past 14 years (eas Figura 4). Tarumal last erupted Decamber 1978-Mey 1979, but no eruption has occurred during the current increase in sels-

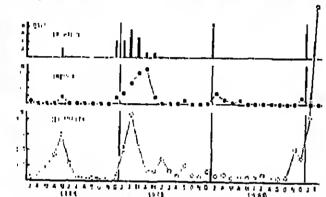


Fig 3. Monthly numbers of days in which occurred: eruptions (top): harmonic iremor evenie (center); and recorded eerthquakas (bottom) st Terumai, January 1979-Fabruary 1991.

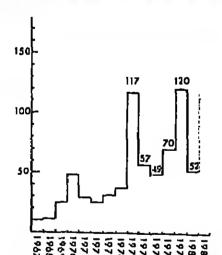


Fig. 4. Yearly means of monthly seismicity, 1967-1980.

information contect: Safsmological Division, Jepan Malaorological Agency, t-3-4 Otamachi, Chiyoda-ku, Tokyo 100,

Earthquakes

4

Dele	.	Time. GMT		Latitude	Longitude	Depth of Focus	Region
Fab.		1320	5 4 m ₀	38.45 N	1.66 E	10 km	North- ern Al- gerie
		0609	5.5 M _L	46.3511N	122.238°E	7.3 km	12 km north of Mt. St. Helene
		1728	4.9 m ₀	41.05 N	14.70 E	10 km	South- em lie
		1519		21.60 S	199.3 5 "€	6hallow	Loyelty lelands region, South Pacific
		2054	6.7 M,	38.21°N	23.02°E	shellow	Greece
		0236	6.4 M ₃	38,16 N	23.15 E		Greece
Mar.		2158	65 M.	38.31 N	23.43'E	Shatlow	Greece

The February 1 event caused the collapse of saverei buildings damaged by seismicity in the El Asnam aree, where earthquakes on October 10 killed (housande and left about 400,000 homeless. Eight people died of heart attacks triggered by the fally earthquake, which occurred near the apicenter of the devastating November 23 shock that killed

several ihousand persons. There were no reports of ceeueitles or damage from the Loyelty Islende event. The Greek eerthquekes killed 21 people and injured 400, white ceueing coneiderable damege in the Athens and Corinth erees. Numerous smeller shocks occurred between the three events listed abova.

information contacts: Netlonal Earthquake Information Servica, U.S. Geologicsi Survey, Stop 967, Denver Federel Center, Box 25048, Denver, Colorado 80225.

Stevan Msione, Chrisline Boyko, Elliot Endo, end Crefg Weever, Gradueta Progrem in Geophyeice, University of Waehington, Seettle, Weshington 98195.

Austrie, Januery 28, 225819 GMT. The following is e report from Zdeněk Cepleche

A fireball of -8 ebsolute magnitude was photogrephed by Ihrea Czech stations of the Europeen network. The ilrebell treveled a 41-km luminous trejectory in 1.8 e. The following results are based on all evalieble photographe from rather distant stetione (210 to 290 km from the trejectory).

	Beginning	Meximum Light	Terminal
Velocity, km/s	26.4	27.4	9
Height, km	72.7	59.9	39.3
Latituda	47,234°N	47,30°N	47,424°N
Longitude	15.147'E	15.1 t°E	15.044°E
Megnitude	- 3.5	- 9.1	-3.5
Mees, kg	0.9	0,9	none
ZR	33.3°	_	33.5°

Firebell type: Meleorite leit very improbable.

Radiant, 1950.0	Observed	Geocentric	Heliocentric
Alphe	136.9°	136.5	_
Delta	15.4°	. 14.1°	_
Lembda	-	_	62.6°
Bete	-	_	-1.3°
Initial Velocity, km/s	28.7	26.4	37.1
Orbit, 1950.0			
A	2.08 AU		
E	0.793		
Q	0.430 AU		
Aphelion	3.7 AU		
Omega	105.8		
Ascending node	129.519		
Inclination			
Inclination	1.9		

Mateor Shower, A bright member of Pel Leonids not excluded.

Informetion contact: Zdeněk Cepische, Ondřejov Obsarv elory, 251 65 Ondřejov, Czechoslovelde.

Labredor See, Decembar 31, 1980, 0132 GMT. Observers: Capl. Schoune, F/O Ven Themscha of Sebene Filght 568 (Chicago-Bruesels). Location: 55.62° N, 44.85° W, aircraft coursa 110° mag-

First sighting: 20° megnetic, 20° abova the horizon. Last sighting: 0° magnetic, at the horizon.

Duration: 1/2 5.

Brightnass: As bright as the full moon. Color: while.

Information confect: Sama as for Wast Garmany.

Gulf of Thalland, January 11, 1226 GMT. Obsarvere. Capt. De Montblanc, F/O Lagrein, F/E Gooseans of Sebene flight 272 (Kuala Lumpur-Bengkok). Location: 8.2° N, 100.38° E, aircraft coursa 009° magnatlc. altituda 10.5 km.

First eighling: 30° magnetic, 30° abova the horizon. Last eighting: 90° magnetic, at the horizon. Duration: 5 s.

Brightnass: As bright as the full moon. Tha object had a round, whita-blue haad end a vary long,

streight, brifflent yallow tell. Information contact: Sama ae for Weat Germany.

West Germany, January 30, 1717 GMT. Observer: Capt. Luabbert of Lufthansa tlight LH 948 (Hamburg-Stutigart).

Location: 20 km south of Leine (just north of Kessel), aircreft course 190° magnatic, altitude 10 km.

First eighting: 170° megnetic, 40° ebova the horizon. Lest sighting: 195° magnatic, 8° above the horizon. Duretion: 2 s.

Apparant brightnaee: As bright es tha full moon. The circuler white object moved very elowly. No disinlegretion was observed before it diseppeared.

Information contact: Gerhard Poinitzky, Universitests-Stemwarta, Tuerkanschenzstrasse 17, A-1180 Wien, Aus-

Northarn Italy, August 13, 1980, 0200 GMT. Observers: Silvano Ghedini, Luigi Baldinelli, and Andres

Locetion: Bologne, Itely (44.5° N, 11.33° E).

First eighting: right esceneion 2 h 30 min, declination Last eighting: right ascension 18 h 00 min, declination

Magnitude: -15. Color: green.

36.10

33.45

32.51

4.994

9.021

Trein: pereletent Information contact: Same as for southern Europa.

Austria, Jenuery 29, 182530 GMT. Tha tollowing is s raport from Zdeněk Caplecha.

A very elow-moving firabell of -9 maximum absolute magnitude was photographed by two Czech etetions of the European network. The Ilrabell traveled e 54-km luminoue trajectory in 5.1 s. Tha time of the fireball peseaga depends on thrae visual observations in Auetria reported to ue by Dr. G. Poinitzky. The following reaulte are based on the two photographic records.

Maximum Light Torminal

		Degmini	ia waxiiuni	n Lignt	• Ormina:
Velocity, km/e Height, km Letitude		11.59	11,10)	6.68
		67.0	49.1		32.6
		46.333°	N 49.36	3° N	49.4176° N
Longitud	е	14.449°	E 14.74	P E	14.9918° E
Magnitud		- 2.3	- 9,g		-2.7
Mase, kg	1	20	15		1.0
Z #		50,4°	_		50.6
Time, a	Helght, km	Velocity, km/a	Deceleration, km/s²	Dynemic Mess, kg	Photometric Mess, kg
0.0	63.79	11,539	-0.067	20.1	20.4
1.0	58.47	11.429	-0.192	19.9	19.0
2.0	49.28	11.199	~0.392	18.5	15.7
3.0					6,8

Assumed density of the meteoroid: 2.2 g/cm³ Dynamic and photometric masses are in excellent agreement. A metaorite tell of about 1-kg maee le quile certain.

-2.29

-3.55

Predicted Impect eree: 48.4276° N ± 0.0040, 15.1320° E ± 0.0105 (naar Treunatein, Aueirle).

Predicted meteorite type: carbonaceous chondrile. The activities in the search aree will be organized by Gerhard Pointzky, University Observatory, Vienna (see information contact. Labrador Bey Fireball for eddress).

Radiant, 1950.0 Alpha	Observad	Geocentric	Heliocentr
	5.9°	348.7°	_
Delte	20.6°	0,3°	
Lembde	_	_	33,48
Bete			0.68
Initial Velocity, km/a	11.61	4.01	32.90
Orbit, 1950.0			
A	1.234 AU		
E	0.225		
Q			
	0.9591 AU		
Aphallon	1.512 AU		
Omege	147.4°		
Ascending Node	309.11*		
Inclination	0.69°	_	

Information contact: Seme ae above.

Southern Europe, Novembar 11, 1980, 1736 GMT. Maurizio Eliri provided the ioliowing edditional observetions of this firaball from Italy, supplementing the re-

information contact: Maurizto Eltri, Sezione Meleore, Unione Astrofili iteliani, Vis Mercantonio Bregadin No. 2, 30128 Lido, Venezia, italy.

e raninne	rouOlinge	Of Focus	Region	port on pp. 12	2-13 of SEAN Bullat	lln, 5(11).			of Toriozia, Italy.		
38.45 N	1.66 E	10 km	North-	Observer	Location	Trejectory	Duration	Magnitude	Color	OlasiOhan -	Trein
48.351°N	122.238'E	7.0 km	gerie	Bruno Peneo	Lido, Italy	NNE to SSW		- t0	Blue-Whita	Size/Shepe	Old not persisi
-5.05111	122.250 €	7.3 km	north of Mr. St. Helene	Luigi Baldmeiii	(45.4° N, 12.4° E) Bologne, liety (44.5° N, 11.3° E)	From RA 1 h 50 min, decl. +47° to	6-7 e	~15	. —	Diameter of the	Parsistani ler
41.05 N	14.70'E	10 km	South-	Ferrucio	Pegli, Itely	RA 19 h 45 mln, ded. +3°				moon	15 min, possi- bia final fiara
21.60°S	100 05:5		ly	Castall	(44.38° N, 9.82° E)	SSE to SW		<u> </u>	Oranga-green	35-min diemeter.	
21.00 5	199.35°E	shallow	Loyelty lelands region, South	Luciano Tesi	S. Marcello Pistolese, liely (44.05° N, 10.78° E) Pistole, Italy (43.93°	NE sky to SW heri- zon, passed 3° east ol zele Cygnus	_	~10 to -12	While-blus with green-red helo	droplika form	
38.21°N 38.16°N	23.02 E 23.15 E	shellow	Pacific Greece Greece		N, 10.96° E)	From zenlih to Sag- itiarius toward moon, neer Vaga in cygnus	5.8	10 to - 11	Blue-green	· . · - · .	_
38.31°N	23.43'E	8hallow	Greece	P. Fapperdue	Viterbo, liety (42.40° N, 12.10° E)	From 50° altitude NNE to SW horizon	10 e	-17.5	Orange; fragmen- tetion with some	Diameter of the moon (30 min)	Persistent for 2-3 a
nt caused seismicity October	in the Et.	Asnam o	nao.		Nepl, lialy (42.23° N. 12.35° E)	NE sky to W horizon	_	- t3	parts becoming while, mag - 1		-
es. Eight p earthquake laling Nov) Which oc	d of hear	attacks		Rome, Italy (41.9° N, 12.5° E)	NE sky to W horizon	3 8	-15	Central part white	A R. M. L. M. L. M. L. L.	irregular over 20°-30°, red- green color
	911061.23	SHOCK (U)	at Kaled	None of tha	observera reported any	sounds.	3-10		· · · · · · · · · · · · · · · · · · ·	16.	gloui .

Western Czechoslovakle, January 30, 223230 GMT. The following is a report from Zdeněk Cepleche

A firebell of -8 maximum absolute megnitude was photogrephed by two Czech stations of the European network. The firebell treveled a 34-km luminous tralectory in 24 e. The following date resulted from the two photographic records.

	Beginning	Meximum Light	Terminel
Velocity, km/e	19.2	14.9	9.3
Height, km	69.3	46.4	37.2
Latituda	50.312° N	50.24° N	50.212° N
Longitude	16.326° N	16.28° E	16.256° E
Megnituda	-2.7	-6.0	-2.3
Mass, kg	2.1	1,0	None
28	20.9°	_	20.9°
Fireball type: II Melecrite fell vary	improbabla.		
Redient 1950.0	Observed	Geocentric	Hellocentric

Redlent, 1950.0	Observed	Geocentric	Hellocentric
Alphe	149.7°	150.1°	_
Delta	97.9°	70.6°	_
Lambda	_		52.4°
Beta		_	16.3°
initial Velocity, km/s	16.28	11.91	33.75
Orbit, 1950.0			
A	t.341 AU		
E	0.327		
Q	0.903 AU		
Aphelion	1.76 AU		
Omege	228,9°		
Ascending Node	310.532°		
Inclination	16.6°		

Meleor Shower: Early mamber of Cameloperdelide not quite excluded.

Information contact: Same as for Austrie.

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at the essistant to associate protossor level. Appli-

conia with backgrounds and specialities in seismic

teech undergraduate and graduate courses, and lo

pursue an active research progrem with greduate

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search programent nos modern leading and research programe in geology and geophysics, and
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seerch utilizing e new POP 11/70 computer; morti-toring of the Intermountain setsmic bett by e 55 sta-lion telemetered network utilizing a new on-line POP 11:34 computer; major experiments in satismic retraction and reflection profiling for crusial atruc-ture, and effect research in factonophysics of

mountain building.

The closing dete for epplications is Mey 1, 1981 and the appointment date is September 1981.

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Applicants should submit e vita, transcripte, e letter describing his/her research end teaching goals, and names of five persona for ratarence. Qualified persons should eand their expilications to William P. Nesh, Chairman, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah 84112.

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and twelve house of physics, and will utilize to a great degree the research staff and lacilities in the co-sponeoring departments of eviction and geogra-

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Candidates should send resume, statement of research interest, and addresses of three references to L. D. McGinnie, Chairman, Depertment of Geology, Northern Illinois University, DeKeth, IL 80115.

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Visiting Assistant Professor. One-year, temporary position available August 1981 to tasch mineralogy, general geology, and perhaps optical mineralogy. The euccessful candidate will be required to be a temporary of the euccessful candidate. quired to leach three courses during a two-sensa-isr year; someone who enjoys leaching is needed. Persons on leave are encouraged to apply. Dead-line for applications is April 17, 1981. Please send resume to David Krinsley, Department of Geology, Artzona State University, Tempe, AZ 85281. ABU is an equal opportunity employer.

Chemical Oceanography/Marine Geochemistry. Anticipated faculty opening at Florida Biele. University. Applicants from all appelialities welcome preference to candidates who anhence existing programs in marine and atmospheric chemistry.sedimentary geochemistry and radioonemistry-Contact, Chairman/Chemical Oceanography Search Committee, Department of Oceanography: The Florida State, University, Tallahassee, FL 32306, Telephone 904/844-8700.

princeton University/Scientific Programmers and Data Anelysta. The Geophysica Fluid Dynamica Program of Princeton University seeks applicanta for two full time scientific program seeks approximate to two tentume scientific programming positions that may become evallable in July 1981. These programmers will become part of a research group that is making use of measuraments of a variety of chemicals in the world oceans to learn about oceanic circulation and mixing. One position includes death analysis and the intersition involves date anelysis and the other involves developing computer simulations.

Applicants should have a bachelor's or master's

Applicative should have a bachelor's or master's degree in oceanography, physics, chemistry or anglineding with a strong meth background. Fortran programming and course work in oceanography are required. Salary is \$15,000 to \$17,000 per year.

Send a resume, course transcript and names of 3 references to Prol. Jorga L. Sarmiento, Oirector, Geophysical Fluid Dynamics Program, Princation Inversity, Princeton, NJ 08644. Princelog University is an equal opportunity/almative action amployer M/F.

Faculty Position in Occomography/Occio-syr University of Northarn Coloredo. The Ospariment of Earth Sciences invites applications

for a full-tima, tenure track faculty position in oceanography, starting September 1881. We are seeking a person with a broad background in seaving e person with a broad background in oceanography and one or more of the related earth sclenca lields such se marine geology and/or sed-imentology. Major responsibility will be teaching be-ginning and advanced courses in oceanography, courses in the related field, and general education courses in the retated field, and general economic courses. A modest amount of research is possible and is encouraged. Applicants should possess the Ph.D. degree of be in the final stages of completion of that degree. Starting rank and selary will depend on experience and other qualifications of the candi-

Applicants should submit a resume and at least three letters of recommendation to Dr. L. Glen Cobb, Cheirman, Department of Earth Sciences, University of Northern Colorado, Grealey, CO

The deadline for application is Mey 10.

COURSES

Course No. 401: Inversion Methods is Remote Sensing, Aloxandris, VA. MAY 18—22, 1981. The course is intended to provide s

basic understanding of the concepts and an overview of applications of the increasingly important lield of inversion methods in remote sounding and is eliuctured to benefit those involved in the theoratical, esperimental, data analysia, ond managa ment aspects of remote eensing aspartmenta to monitor the strospheric constituents and proper-ties from ground, airborne, or space platforms. The adventages, limitellons, and luturo prospects of each technique will be discussed. Instructors will be Drs. M. Chahina, B. J. Conrath. A. Doapak, B. M. Hermen, W. L. Smith, D. H. Staelin, and E. R. Westwaler, Registration fee is \$460.00.

A Certificate of Course Completion will be awarded to those who complete each course. For further Information, contect: Nency Reynolds or Sus Crotte, Course Coordinstors, IFAORS, P.O. Box P. Hampton, Virginie 23866 (Tal: 804/827-5811).

STUDENT OPPORTUNITIES

Metaorology and Physical Oceanography
Assistantships Ior graduate students in meteorology and physical occurr-ography are available from The Floride State Uni-

dynamics, physical meteorology, synoptic meteorology, cilmetology, numerical weather prediction, physical oceanography, chamical oceanography, ocean modelling, setallite oceanography and sacphysical fluid dynamics

Appointments ore helf-time and olfer ealerise up to \$10,500 per year. Beginning graduate students may be offered salaries as low as \$7,200 Students with undergraduate degrees in physics, chemistry, mathematics, atolistics, mateorology, oceanography

and angineering are encouraged to apply
Additional information may be obtained from Dr.
James J. O'Brian, Masoscala Air-See Interaction
Group, The Florida Stata University, Tallahesseo,

SUPPLIES

Rook Hemmer with pick haad and taathar holstar for \$16.00. This is \$8.00 balow list pnce. Write for free catalog "Geologic Field Supplies and Pros-pecting Equipment". Western Haritaga, 101 S Washington St., Hinsdeta, IL 60521. Talephone (312) 864-5228.

Meetings

AGU Front Range Branch 'Hydrology Day'

The AGU Front Ronge Branch is sponsoring o HYDROLOGY DAY on Thursday, April 23, 1981 at Colorado State University in Fort Collins, Colomdo.

All sessions are in the Student Center.

Session 1 Student Papers 8:15-10:15 Duane HAMPTON (Ph.D.) Mechanisms of Coupled Heat and Water

Jayantha T. B. OBEYSEKERA (Ph.D.) Physically Based Stochastic Models for Seasonal Streamflow

Roy W. KOCH (Ph.D.) A Physically Based Derivation of the Distribution of Excess Precipitation

Francisco N. CORREIA (Ph.O.) A Rainfall-Runoff Model Using a Generalized Unit Hydrograph Theory and Modern Infiltration The-

Session 2 Student Pepers 8:15-10:15 Thomas W. ANZIA (senior) A Comprehensive Table of Standard Deviales for Confidence Limits on Extreme Events

Victor NAZARETH (M.S.), Aquifer Properties from Single-Hole Aqui-Jim HYRE (M.S.), Experimental Investigation of Ponding Time and Soil Water Content Evolution

Andres CARDENAS (M.S.), A Conceptual Model for Predicting Session 3 Professional Papers 10:30-12:00

Comparison between Overland Flow Model and Expanimental Data, D. D. Adrian and C. J. Martel Livestock Grazing Management and Nonpoint Source Water Quality Assessment, Eric B. Janes

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These who are intending to patticipate is the IAGA Edinburgh but do set yet have the Second Circular and Registration

Dr. S.R.C. Hallo Secretary. Organising Committoe for IAGA Assembly Geomegnetism Unit, Institute of Geologice) Stiseces Natchison Bouse, West Maies Road Ed)mbetgh 189 3LA, Storland, N.F.

Srientiflo results from the MAGSAT electors: S.A. Laugal C.S. Harreslough

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Rainfall Simulation to Determine Grazing Management Effects on Upland Hydrology, P. L. Gustalson, R. P. Julander and E. B. Jones LUNCHEON: Speaker, Dr. Jeris A. Dantelson

Sasaton 4 Profassional Papara 1:15-5:00 Repeat Measure Analysis of Variance of Rainfall Simulation Plot Hydrologic Response, S. D. Hudson, P. L. Gustalson and E. B. Janes Work of Water and Power Resources Service in the Application of

Remote Sensing to Water Resources Investigations, Jim Verdin Multivariate Models of Residential Water Demand: A Case Study of Denver, Colorado and Its Metropolitan Area" Chue Jones and John Monts

A Dilemma: Too Much Water in a Denver Development, Jim Jehn Prediction of Natural and Man-Induced Bedford Transport in Steep Western Streams, Donald H. Simpson and Donald O. Doelming Hydrologic and Hydraulic Analysis of the Middle Rio Grande, Robert

An Approach for the Detection of Changes in Water Quality Vana bles, R. W Koch and T G Sanders Run and Range Properties of Shifting Level Models, J. T. B. Obeyse kers. J D Salas and D. C. Boes

For registration and transportation information, contact HJ Morel. Seytoux, A305 Engineering Research Center, Colorado State University. Fort Collins, Colorado 80523. Phone (9)31.494.4549. Transportation is being arranged from Denvei. Boulder Golden, and

New Listings

June 22-28 Infornational Symposium on Erosion and Sediment Trensport Measurement, Florence, Italy. Sponsors, IAHS, International Commission on Continental Eiosion, Nellouel Research Council of Italy. (P. Tacconi, Secretary of the Organizing Committee, Istituto di Ingegnerie Civile VIa S. Marte, 3 50139 Firenze, flelv.)

June 29-July 2 22nd United Steles Symposium on Rock Mechanics, Cambridge, Mess. Sponsor, Massachusetts Institute of Technology. (Barbara Dullea, Coordinator, Center for Advanced Engineering Study Seminars, MIT. Cambridge, MA 02t39.)

Nov. 9-20 Second Symposium on Geodesy in Africa. Nairobi, Kenya, Sponsors, IAG, IUGG Local Committee ol Kenya, IUGG Committee on Advice to Developing Countries, African Association of Cartography 1R Omandi, Survey ol Kenya, P.O. Box 30046, Nairobi. Kenya.}

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Apr. 11-16 Penrose Conference on Antarctica, Shenandoeh Nationel Park, Ve. Sponsor, GSA. (lan W. D. Dalzell, Lemont-Doherty Geological Observatory, Columbia University, Pelisedes, NY 10984.)

Aug. 22-26 Third Circum-Pacific Energy and Mineral Resources Conference, Honolulu, Hawaii. Sponsor, IUGS (AAPG Convention Department, P.O. Box 979, Tulsa, OK 74101.)

Information on the IAGA Edinburgh Assembly

	Hill	OTIN	iation on the IAGA Edinb	urgn At	sembia	
The Fourth General Scientific Assembly of LAGA will be held in Ediabutgh, Acciling, G.K., from 3 to 15 August 1981, is response to the institution from the Foreign Section 2.		2	Properties of ceruist and againstic rigano-	6.4. Litrava 9. O'tellly	,	
the Royal factory of London through its National Subcommittee for Generalizated Associaty. H.R.H. The Printe Philip, Duke of Edinburgh, Chantaflor of the Chivasoity of Edinburgh, has graciously consented to art of Patton of the Associaty	112	2.5	Physical and chesical procures of suggesting overprinting in relation to geological scenia	l. E-Jies E. Holler D.J. Contop	'	
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> ber your 20% discount Ust Price \$5.00

American Geophysical Union 2000 Florida Avenue, N.W. Washington, D.C. 20009



1981 AGU Spring Meeting

Ballimore, the sile of the AGU Spring Meeting, May 25-29, is enjoying a major urban renalssance. Nowhere is this more apparent Than in Metre Center, the 1000-acre downtown core of Baltimore. The convention conter, an ultramodern meeting lacility, is only a short walk from Harbor Place. Harbor Place is a ekylighted, lerraced conglomoration of more than 20 wolorsida roslaurants and over 100 bouliquee.

Hotel Accommodation. A block of rooms is being held at three nearby hotels; the Baltimore Hillon, the Lord Baltimore, and the Holiday Inn-Downtown. The Lord Baltimore and the Hillon are connected by a covered walkway. Read the housing application and MAIL THE COMPLETED APPLICATION FORM TO THE HOUSING BUREAU early to insure confirmation of preferred hotel.

Registration. Everyone who attends the meeting must legister. Preregistration (received by May 8) saves you ilme and monoy, and the lee will be retunded if AGU receives writion nolice of inability to altend by May 15. Registration rates aro as follows:

	Preregistration	Al Meeting (atler 5/8)
Membar Sludont Member	\$45	\$60
Nonmembor	\$25 \$65	\$40 \$ 85

Registration for 1 day only is available at one half the above rates. Membars of the American Meteorological Sociely, the American Society of Photogrammetry, and the

American Congresa on Surveying and Mapping may regieter tor the meeting at the AGU member rates.

Studenta who are not AGU membera abould send in an application form with their registration payment. The ditleience between mamber (or student member) registration and nonmember registration may be applied to AGU dues II a completed membership application is received at AGU by Auguel 3, 1981. Curreni AGU annual membership rates are: \$20 members; \$7 student members.

To preregister, Illi out the registration form, and return it with your payment to the AGU Office. When payment is made by an organization, please attach the form wherever possible; or be certain that your name and other pertinent information is on the check. Your receipt will be included with your preregietration material at the meeting. Preregistrants abould pick up their registration material at the preregistration desk at the Convention Center. (On Sunday, from 5-8 P.M. in the lobby of the Hilton hotel).

The program and meeting abstracts will appear in the April 28 Issue of Eoe, which lamsiled to all members in advance of

Complimentary badges for queste not attending the scien-Illic saasions will be available at the registration desk.

Sociel Events

An array of evening activities includes the Ice Breaker on Monday; the awards presentation honoring fellow adentists at a ceremony open to all participants, followed by a reception, on Tuesday, and an evening of tun and exploration on Thuisday at the Maryland Science Center.

Business Luncheons

There will be eight section luncheons; Geodesy, Geomag netism and Pateomagnetism, Hydrology, Oceanography, Planetology, Selsmology, Solar-Planetary Relationships and Volcanology, Geochemistry and Petrology, (epace is limited)

Wednesday, May 27, 1981

Gsodsey		Ime
Place	Chiapparelli's Restaurant 237 South High Street	пооп
Hydrology		
Place	Caesar's Den 223 South High Street	12:15

Ocsenography

Program:

Place

"The Impact of Satellitee on Futurs Oceanographic

W. Stanley Wilson, NASA

Velleggla's Restaurant Corner of Pratt & Albemarie

SAIL INTO **AGU Spring Meeting** May 25-29

HOTEL ACCOMMODATIONS

PARTICIPATING HOTELS	HOTEL CODE	ROOM RATE		
Baltimore Hitton Hotsl 101 W Fayetlo St. Baltimore, MD 21201 [301) 762-1100	ВНОТ	Single: \$43.00 Double: \$58.00 Twin: \$58.00		
Holidey Inn-Downlown 301 W. Lombard SI Balkmore, MO 21201 (301) 685-3500	нот	Single: \$35.00 Double: \$38.00 Twin: \$44.00		

Lord Battimore Holel LBOT Single: \$33.00 Baltimore & Hanovor Double: \$39.00 Twin: \$39.00 Streels Baltimore, MO 21201 (301) 539-8400

EXTRA PERSON Hilton/\$16.00 Lord Ball Imore/\$8.00

Hollday Inn/\$7.00

PARKING

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SUITES

Hitton • Parlor plus one bedroom suite/\$126.00-\$190.00 Parlor plus two bedroom suite/\$250.00

Be sure to enter the eppropriate cods lettere on the etteched form. Kesp this sheel for your records, and forwerd the housing application form to the housing bursau et the address indicated.

All hotel reservations must be made on the housing form by April 24, 1981. No telephone requests will be eccopied. Conlimnations will be meiled direcily to registrants by the individual hotels. After continuation has been received, changes and cancelletions should be made willt the hotel dirocily.

Any question regarding your holel accommodalions should be made in writing lo:

> Housing Coordington AGU Spring Meeting **BallImore Housing Bureeu** 1 West Preil SI. Balilmore, MD 21201

PLEASE COPY THIS INFORMATION FOR YOUR RECORDS

American Geophysical Union Spring 1981 Meeting

May 25-29, 1981 Baltimore, Maryland

> Mall thie form to: Housing Bureau 1 West Prett St. Baltimore, MD. 2120t

HOUSING APPLICATION FORM

READ CAREFULLY:

Please print or type (pica apaced) all information abbreviating es neceeaery. Confirmation will be sent by the hotel to the individual named in Pari I. If more than one room is required, this form may be photocopied.

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INSTRUCTIONS: Select THREE Hotel/Motele of your choice from the flet of perticipating fecilities, then sales the appropriate code lettere in the boxes below.

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*AGU housing registration dasdline is April 24, 1981

PART III

INSTRUCTIONS: 1. Select type room deelred with arrival and deperture datee. 2. PRINT or TYPE namee of ALL persons occupying room.

3. If more than two people shere e room, check twin and the

SINGLE (Room with one bod one person) DOUGLE (Room with one bed two persons) TWIN (Room with two beds two persons) P+ 1 (Parior plus one-bedroom suite) P+ 2 (Parior plus two-bedroom suite)	Arrival Date MO DAY Departure Date MO DAY Arrival Time Ph	Guest Names (Print Leet Name First) 1. 2. M M 3	· · · · · · · · · · · · · · · · · · ·
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IMPORTANT NOTE: Hotel MAY require a deposit or some other form of gueranteed arrivel. If so, instructions

Pienetology

Trattorie Petrucci 12:30 300 South High Street

Thursday, May 28, 1981

Sejamology Program:

Place

Place

A Scientific Talk: "Reference Earth Model and Beyond"

Adam M. Dziewoneki Hervard University, and Don L. Anderson, California Institute of Technology

Kinemetrice, Inc.

Teledyne industries inc.

W.F. Sprengnether Instrument Co., Inc. Antonio'e Reetaurant

925 Eastern Avenue

Soler-Plenetary Reletionships

Role of AGU in Politicizing Public Policy for Science (tentative)

Ned A. Oeteneo, Chairman, AGU Public Affairs Committee

Sponsor Martin Marletta Aerospece, Denver Division

Place Velleggia'e Restaurant 11:45 Corner of Pratt & Albemerle

Geomegnetiam and Peleomagnetiem Place DeNittle Restaurant

Volcenology, Geochsmietry, end Petrology Sebatino'e Resteurant noon

901 Fawn Street

906 Trinity Street

Check the appropriate apaces on the registration form and Indicate number of reservations. Details of these activities will be published April 28th in the abstract issue of EOS. Follow the Sall Into Baltimore update.

PROGRAM SUMMARY

Union

Climate Variebility (Monday PM) Voyager I Selum Results (Wednesday AM) History of Space Research (Wednesday PM) Ground-Water Quelity (Thursday PM) lo (Thursday PM)

Speciel Sessions

Decade NA Geology (GSA) (Monday PM) Overview of NSF Programs (Tueaday PM)

Geodesy

Seaset-Geodesy (Wedneeday AM) Geodesy I (Thuraday AM) Geodesy II (Thursday PM) Geodeey III (Fridey AM)

Geomegnetism end Pelsomagnstiem

Tertiary Paleomagnetiam (Monday AM) Paleomeg/Megetectonica (Mondey PM) Em Induction I (Tuesdey AM) EM Induction II (Tuesday PM) Magaat-I (Wedneaday AM) Megsat II (Wednesday PM) Peleozoic/Precambrian (Wedneaday PM) Geomagnetic Fluctuatione (Thursday AM) Magnelization Processes I (Thursday AM) Magnetization Processes II (Thursday PM)

Hydrology

Efficacy in Modeling (Monday AM) Acid Rain (Monday PM) General Surface Water (Monday PM) Urban Runoff I (Tuesday AM) Desertitication (Tuesday AM) Urban Runoff II (Tuesdey PM) Water and Synthetic Fuela (Tuesday PM) John Ferria Symposium I (Wednesday AM) John Ferria Symposium II (Wednesday PM) Drinking Water and Health (Wednesday PM) Organics in Ground Water (Thursday AM) Geochem and Waler Quality (Thursday PM) General Groundwaler (Friday AM)

Metsorology

12:45

SEASAT-Meteorology (Monday AM) Atmospheric Chemialry I (Tuesday AM) General Meteorology (Wednesday PM)

Oceanography

Seasat Oceanography I (Monday PM) Seasat Oceanography II (Tuesday AM) Paleo-Oceanography (Tuesday AM) Seaeat Oceenography III (Tuesday PM) Chemical Tracee (Tuesday PM) Shell Circulation (Wednesday AM)

Marine Sediments (Wedneaday AM) Deep Oceen Currents (Wednesday PM) Marine Geology (Wednesday PM) Small Scale Physice (Thursday AM) Hydrothermal Proceeses I (Thursday AM) Hydrothermal Procesaes II (Thursdey PM) Physical Processes-Modela (Thursday PM) Physical Processee (Friday AM)

Plenetology

Voyager Reaulta (Wedneaday PM) Plenetery Surfaces (Thursday AM) lcy Bodies (Thursday PM) Venua Atmosphere I (Friday AM) Venue Atmosphere II (Friday PM)

Seismology

Prediction and Strong Motion (Monday AM) Selemicity end Tectonice (Monday PM) Cruetal Structure (Monday PM) Reflection and Refraction (Tuesday AM) Source Processee (Tuesday AM) Seismic Source (Tuesday PM) Earth Structure I (Wednesday AM) Earth Structure II (Wednesday PM) Networks and Locetions (Thursday AM) Normal Modes (Thursday PM)

Soler-Planetery Reletionships: Aeronomy

Spectroscopy in Geophyeics (Monday AM) Spectroscopy In Geophyeics (Monday PM) Thermosphere (Tuesday AM) Atmospheric Chemistry II (Tuesday PM) Almospheric Chemistry III (Wednesdey AM) Atmospheric Chemistry IV (Wedneaday PM) Chatanika Radar I (Thursday AM) Chatanika Radar II (Thursday PM) Ionoapheilo Irregulariliea (Friday AM)

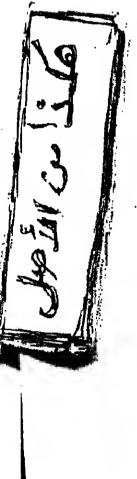
Solar-Plenetery Reletionships: Cosmic Rays

Cosmic Rays (Monday AM) Ploneer to 25 Au Crosaing (Tuesday PM) Flare Composition (Wednesday AM) Shock Acceleration (Thursday AM)

Solar-Planetary Reletionships: Megnetospheric Physics

Plasma Instabilities I (Monday AM) Plaema Instabillies II (Monday PM) Birkeland Currents (Monday PM) Geomagnetic Pulsations (Tuesday AM) Auroral Phenomena (Tuesday PM) Theory/Simulation/Expt (Tuesday PM) Auroral Potential (Wednesday AM) Bow Shock (Wednesday PM) Charged Particlea (Thursday AM) VLF Effects (Thursday AM) Magnetospheric Potpourri (Thursday PM)

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Substorm Effects (Thursday PM) Magnelospause Effects (Friday AM) Saturnalia (Friday AM) SPR Date from History (Fridey PM) Salurn end Jupiler (Friday PM)

Solar-Planatary Relationships: Solar and Inter-Planatary Physics

Soles Almosphere (Monday PM) Solar Wind (Tuosdey AM) Soler Wind Turbulence (Thursday PM) Flare Acceleration (Fridey AM)

Teotonophysics

Hoi Spois and Convection (Monday AM) Crustal Geophysics (Monday AM) Ocean Evolution (Mondey AM) Tectonics of Venus (Mondoy PM) Minols Deep Hole (Monday PM) Gravity, Isostasy and Flexuro (Tuesday AM) Equation of Stete (Tuesday AM) Heat Flow and Thermal Prop. (Tuesday AM) Stress and Strain (Tuesday PM) Non-Brittle Deformation (Wednesday AM)

Thin Skin Tecionica I (Wednesdey AM) Fracture end Faulting (Wednesdey PM) Thin Skin Tectorics II (Wednesday PM) Subduction and Convergence (Thursday AM) Ridgee and Rilling (Fridey AM)

Voicanology, Geochemiatry, and Petrology

Arcs end Ophiolies (Monday AM) Geochemiatry I (Monday AM) Geochemialry II (Mondey AM) Kimberlliea (Mondey PM) Crysiel Structure (Tueedey AM) Evolution of Earth I (Tuesday AM) Evolution of Earth II (Tuesday PM) Experimental Petrology (Tuesday PM) Oceanic Voicenic Rocks (Wednesday AM) Silicate Melt Structure I (Wednesdey AM) Silicate Melt Structure II (Wednesday PM) Isotopee (Wednesdev PM) Voicenoee-I (Thuraday AM) Volcanoes-II (Thursday PM) Melemorphic Petrology (Thursdey PM) Plutonic Rocks (Fridey AM) VGP Polpourri (Friday AM)

MEETING ANNOUNCEMENT LUNAR AND PLANETARY INSTITUTE TOPICAL CONFERENCE PROCESSES OF PLANETARY RIFTING

> December 3-5, 1981 San Francisco Area

CONVENERS: B.H. Baker and P. Morgan SESSIONS PLANNED:

11 Speculations as to the origin and development of rifts 2) Constraints on rift evolution - setting
3) Constraints on rift evolution - geological development
4) Constraints on rift evolution - physics ond chemistry of the

5) Resources associated with elfting 6) Our state of ignorance and its remedy

Attendance will be limited to 60 participants. Send applications to attend with brief, but specific outline of potential contributions to the meeting include a provisional tile if you plau to submit an abstract. Abstract should be automitted to Rilt Meeting, Projects Office, Lunes and Planetary institute, 3303 NASA Road), Houston, Texae 77058, USA. Deadinglor applications is May 29, 1981. Further Information may be obtained from the above address, or phone (713) 486-2150.

GAP

Geodesy, Mapping, and Photogrammetry Volume 19, Number 3

Goodony, Mapping, end Philogentamicity Volume 19, Bumber 3

Tistance, V. R.N., V.D. Berlenblader, V.A. Hyvellev, A.S. H/ISBAY, AND YE.M. NEVMAN. A Variational Method of Regularization in the Adjustment of Free Resident Nets.

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harpables 03755, U.A.1, and U.J. Parol.Ceytosa, An Analytical gravelove is localogal for Mis feteralization of potantizestic head in non-backeticus squifero. Poth steels and undersity fibe tenfitties are entideesd. The analytical gravelore is lawed wyon the area of critarional barelices. It contacts essentially of assuring an appropriate critariogue, areas for both the states or programmer and propriate critarious. ampropriate circulate essentially of assuring an appropriate circulate resists for both the statter properlies and the unknow planticatette feel. The sechalize is applied to several one and two dimensional flow problem where conditions are inscribed by the linearized Foundation applied by the linearized Foundation applied the state of presisting of potentiarable less the analysis force, analysis extends for the associated behavior of the first Dakangest and presentations of the first field are a potential profile for predictions of constraints a potential prefix for prediction of constraints as transport in promisents along states of the Cree useful features of the critical settles a sixtuated features of the critical settles as transport in the appropriate states and the states are application. The appropriation of discretization of sixtuate the interimental of discretization arrans assistants with the use if node systems which are reliced by rany alternative interimal states. (From hatter flow, cast transport, analytical rethols).

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The Films (The Analytic Sciences Corp.,
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moving everage (APRA) models have become
an important tool for radeling and ferecaeting attentions. The fittal stop in
fulliting such models to identifying candidate obtal structures. Some corrion
methods for selecting a final model from
the condidate set are not applicable when
different (ranaformolions of the observations are used by some randidates.
Abetka's information crieries (AIC) and
bethyop's vaterior probability [PP] tritetion can be used to model possibly overage attention and to used to model possibly overage attentions of the Piver. The
terrics indicate that such "objective"
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with care or an invalid model may be
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Vater Secout, Res., Sager, 190194

2170 Show and Ica SADIATION ALSONFILON CONFFICIENTS BY POLYCRISTAL-LURE ICC 1800 600 to TO 1200 on F. C. Gregfell (Department) of Almospheric Solemene.

ter Senat, Ann. Saper 190194

University of Vashington, Boettle, Gashington 981951 and B. E. Perovirb 981911 and 8, 8. Perovich
Absorption weak(rients have been measured lot
bubble-fitoe polyctystallins ica ovet the spectral
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Abstracting a explayed to grow large quantities
of bubble-free ico is presented in detail. The absorption toerlitienta agree very well with previous tasults in the infrared and provide

J. Geophys. Ses., Green, Poper 100082

1175 Soll collector rabory lettperators as a coor mater stress policator

FARMY LEMPERATURE AS A CROT MATER STRESS INDICATOR.

B. U. Jackson (U. b. Water Conservation Liberatory, 1311 in Proadury Mg., Phonnix, Arland 30001; 5. b. Idno, a. J. Reginato, and F. J. Pinter, Jr. fanopy knoprentures, obtained by infrared thereometry, along with vere and dry-builb air tropstatures and as eatloste of net radiation vere used in equations derived from energy balance considerations to talculate a crop versus attrass index (USI). Theoretical lints were developed for the canopy-air temperature difference an related to the six vapor pressure delicit. The CM31 was shown to be equal to if/fp, the ratio of accual to potential syspolication, June aspectissons in lots, planted to whate, reasived post-centiques irrigations at different tiess to create different deptases of water extreme. Pattient variables were measured between 1240 and 1800 ased May fact agt some verkends). The CM31 was looked as a function of rise, closely paralleied a plot of the extrections of the active casting and indications of the lates and disacced. Mater stream, soil contains, plant encopy temperature, infrared charmonstry).

3171 Soil moleture THE USB OF Na/tl MATIOS TO TRACO SOLUTE SOURCES IN A SEMT ARID ZONE A MENI ARIO ZUNE M. Magaritz [Isotope Dept., The Maiteenn Inst. of tclanca, Bebovot, Israel) A. Andlar, H. Koyumdjisky

As J. Dan. Fainvelor interaction with soils is a bajor source of dissolved seits in greendwater. The trousities task between the horid and the acid area is the sectorised by a specific combination of reactions which do out oalst dissubstre. This combination of CaCD; distolstics and best exchange restricts affects the NA/CI tatlo, which is the quantitatively most important parameters and for treeing tilinity sources of groundwater. The increase in the NA/CI tatlo is the coastal plain againer of inval from north to south is related to local rectarge of Na-rich water efter interaction with soils of leassial origie. [Soil tolvelos, saliulty)

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Hit soil moisture

Hydre and he could be continued to the course of the J. Coophys. Rés., Graen, Paper 100242

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3175 Soil moistare
A MATHEMATICAL MODEL FOR PREDICTING MOISTURE FLOW
IN AN UNSAUMRATED SOIL UNDER HYDRAULIC AND TEMPEMATURE GRADIENTS
V. Dakhamamurthy | Dapartmont ei Clvi) inpinsoring, University er Sysketchewon, Seekaigon,
Canada, S7M CNG) and D. G. Fredlund
A incoratical model is prosented to predict
the meistare flew in an unsaturoted soil as the
rossit wi hydraells and importance gradiants.
A parita) differential heaf flow equations (for
above Freating senditiunt) and the two gartial
differential tronsient flow equations | one for
tha water phase and the other for the air phase),
are derived in this paper and solved using a
finite difference teshnique. Darry's law is ested
te doscribe the flew in the water phase will
Fick's law is assed for the oir phase. The constitutive equalines proposed by Fredhad and
Margensien 1976) are seed the delice the railme
change of an unsaturated soil. The simultaneous
selsion of the parital differential aquations
gives the temperature, the pore-water pressure
and the pore-air pressure distribution with space
and the pore-air pressure distribution with space
and time in an smealarsted soil. The pressure
changes can, in tarn, be seed to compale the
quasity of moistages income. Manada and changes can, in term, be seed to compais the questity af moisture tiom. | Unseturated sell, water phase, air phase, translent flow, hest flow, moistare flew).

Mater Resout. Res., Paper 180248

SUIT SOIL MATERIAL SAID THEIR EFFECT OF SURFACE AND SUBSURFACE WATER TRANSFER IN A THORICAL RAISPOREST CATCHERST.

M. Bonell Department of Geography, James Cook University of Borth Quasmaind, Towardlis, Australia hill), D.A. Olimour and D.P. Siculair This peper examines spatial and temporal haterogeouity of the unreac, subsetess and vertical drainage components within and between three sites in a 25.7 be tropical rainforsat enighteen. Our analysis indicates that aniuration overland flow depends on the religiouships between temporal variations in reinfull intensity, ibn upper soil store expanity, and the opaids variation of seturated candestivity in the outself before expanity, and the opaids variation of seturated candestivity in the outself before appeals, and the opaids variation of seturated candestivity in the outself before acquainty and the opaid invitation of seturated candestivity in the outself invitated flow occurring throughout atoms an the upper alopes, but helog confined to rainfall jobsality panks to the lover, include aran during the post-moseon "tranoitional" season. Regression models is addeste their reinfall pulse shape is an important factor determines the proportion of the upper soil etors espacity occupied by unfarthie in turn controls within eite differences, in specific tenoff occopeants between dermines and lag to peak times as short as 24 minutes. Proceedings and soil anisture stabus that prevail in this area. (Falinforest, drainage Hydrological fieldence Bull. vol. 26, no. 1

1175 Bodi anishmia SCALING OF INFILTRATION SHEAVIOUR IS DESSIBILIAN POROUS MYREGALS S. D. Younga Physaics Department, Bothmarca Ruphcisected Heating, Berpandep, Harts, 1252 220, Ruphcisected Heating, Berpandep, Harts, 1252 220, Sincecopia cheractaitatid langths, as used to sitorecopia cheractaitatid langths, as used to sitorecopia cheractaitatid langths, as used to from annauromothic langths conductivity of from annauromothic langths openauries at Baif-sature-saturities and in the cheractail of hydraulic confustions.

ALET ROSOUL, Res., Poper It dlos

1180 Water Quality
THE OFFIN OF FAINVALL-EUNOFF-SOIL INTERACTION
DETURNISHED BY 22p
L. S. Abnjajugha-SEA-AR, doathere Flains
Whetabase and Water Quality Laboretory,
Derunt, OK 74701) A. W. Obstplay, N. Zamemoto,
and E. O. Hearal
This study dealt with the extent sad dynamics
of a thin zone of soil that interacts with
rainfail and everland liow in releasing soil
chardes is to runoff. A teletively immobile
trater, 15p, was applied at 0.0 taoil surfated,
0.t, 1.0, 1.t or 2.0 cm dapths in duplicate
soil boxes of three different soils. Eluminate
fainfail of 0.5 cm/br was applied on each soil
box for two separate 20-min perfode. The dapres of interaction decreased very capitity,
more or isse exponentially, with depth below
the surface. An uffortive secress depth or
mos of interaction, within which che dagree
of interaction squals that of the soil surfact, was assumed to exist. The effective
system depth that a decreased
between 0.1 and 0.3 cm, depending more upon
the period of cainfail than upon the type of
soil. These secress depths were used, slong
with values of total decorable P and the
irections of the 32p eppiled on the soil surface that appeared in runoff, to pradict the
fromentations in twooff, which agreed rather
well with the seasured whose. The vasuretion
of as discrive average depth was. Thus, we lid fromentations in rusoff, which agreed rather will with the seamured values. The vasuaption of so discrive average depth was, thus, velid for F, frameisot changes in the effective average depth of interaction dwing a rainful period wage calculated by using simultaseous P and ³²P concentratians in tunoff, where the fif was applied at the soil surface. The affective sverage depth increased somewhat with time during a rainfail period, especially during the first JO-min mean offsective average depth of interaction, calculated by this method, agreed well with that obtained by the first rathed dearthed above. (Wenpoint pollution, chantal transport). chemical transport). Milor Rosovt, acc., Paper 19020c

trity with soil-water pressure, bur dissialfar zatarials with a wide range of particle stees and shapes. The ratio of the misroscopic characteristic lengths obtained in these three ways showed tittle warledon between materials. Dissensionless variables defined in terms of them were used to scale experiencial results with packed columns of the paterials for wattled downward intitration, for horisonal infiltration, and for wattleat up-materials wars in agreement and fitted theoretically derived relationships for the three structions. Italitation, similar medic theory!

180 Maret quality SARIANCE ESTIMATES FOR A DYNAMIC EUTROPHICATION MODEL OF SACINAM DAT, LARE HUNCH WDBL OF SAGRAN DAT, LABE HIDRON D. Scayle [Great Labes Environmentel Rosearch Laboratory/NOAA, 2200 Washtansv Avo., Ann Arbot, al, 48[d4], E. P. Conala, M. F. Powers, and

ai, sijd4), L. P. Conaia, N. F. Powers, and
j. L. Noody
first-order vertance propagation vet used to
stimets raviance of model output originating from
satinates of uncarrain initial conditions, perasater values, and octornal lead estimates for a
auriese-phytoplankton-rooplankton dynamic sutrophication model of ena segment of Saginaw Bay,
tale laron. Estimated coefficients of varietion
of model output during aummat were not unlike
thous oftloated from accompagates. The major
tource of tariance was persoater raise ratiances.
The model opartonit paramotors, in farms of padel
tessitivity and varience propagation, were
identified by analysis of the predicted correlation matrix. Methods for reducing model output
hariance were assgessied. Valer Resout, Ses., Paper 190448

3190 MELOT QUALITY COPARISON OF FIRST-ORDER ERROR ANALYSIS AND MATE CARLO SEMULATION IN TIME-DEPENDENT LAKE EUROCHICATION MODELS D. Ecoria (Gross lokat Environmental Resourch Maratery/AOAA, 2300 Washfones Avo., Ann Arbur, Wa. 381031, W. F. Powero, R. F. Cenalo, and J. L

Assisting the provers of the continuous of the c heen Monto Carlo and first-order estimates of both state-wallable velees and thoir variances occurs when Monta Carlo output distributions are specified to the state of the state and state of the state are assured to variance seasociated with total populations [i.e., silelee]. Those distributions, however, chongs dramatically in that for annat state variables. For asymmetric distributions, first-order variance asticutes asserted to the total population (i.e., the typical eight species) and Monte Carlo variance anciences measure variability shout the typical component of the total population (i.e., the typical eight species) and Monte Carlo variance anciences measure variability of the mean component (which is more reflective of the total). One must be egultant of these differences when carisating variance suscelated with model projections, vater Resout, Res., Yepes 190395

Hito Water quality
UNATIGE OF HAZIONAL WATER FOLLIPTION CONTROL
FOLICIES: 2. AGRICULTURAL SECTION CONTROL
Lonard P. Glasset (Resources for the Future,
Le., 1711 Mansachusesta Avenue N.W., Moshington,
D.C., 10031) and Henry S. Fuskin
Appliestion of e netioned water network model
Mentic an assiyale of the libely attacts of
University as assigned on the hibely attacts of
University of the section's veters. This snalysts
it beliated superior to presinus assessments
haded hainly on areason satisates without
accounting for the cherecterinaties of the recairing veter or the contribution of pollutants
ign sonsgicultural activities. Best fiteally,
while the advisor assessments consided that triculturally-related pollution problems ere videspread and ublquitqua, this enalysis continues that it is probably enre efficient to itself ediametrelated pollution control pollution eabout control to pollution control pollution about controlled of the nettor's agricultural regions. (Pollution, egricaltural pollution, addissor control, vater quality [5]: policy analysis]

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Meteorology

1710 Boundary layer structures and processes WIND-MATER TUBBEL STRUCKTION OF SMAIL-BOSLE OCEAN ATMOSPHER INTERACTIONS.

IL COSMILE, A. Regamoniferison, P. Hestayer, f. Pasch and A. Favre timelicuted McGanique timilique do la Turbulonco, 11, swenne do Gönfrel lacierc, 13003 Marsellia, Franco).

Various results within I.M.S.T. wind-water factility in the pest ten years, whoroin samil-actid dynamic and thermodynemic sir-ses suchange processes can be partially almoisted, ats reviewed in the light of present ideas on occan-atcomphore interactions. The object hore is to draw sonclusions on both the validity and uselainess of such leboratory studies, Large and email-scale turbulant valocity and temperature fiside witholt good similatity sed general agreement with suriace layet observations but also lateresting departures iron local lactropy. The spectral characteristics of waves in the imboratory are quite similar to short-fatch field date. An inheteently non-linear "dostinant wave" is found to have a major laboratory are quite similar to short-fatch lield data. An Inheterly non-linear denimant wave. Is found to have a major intiluents upon properties and disparsion relation of wind waves in the laboratory as well as in the field. Mind/wave toupling is observed and invastigated through linear and non-linear entimeter. Turbulent heat and mean rechanges, show that avaporation rates and distributions to the laterprated in terms of the accepted search price in the laterprated in terms of the accepted dearly prion for atmospheric suffee layer. These data is a whole damountrate that laboratory situalism on sanil-males sir-mag interaction mechanisms can provide an insight into naturally accurring physical processes. Isi-Sea interactions, laboratory similation, turbulents, wave generations.

J. Goophys. Res., Gtose, Paper 100356

3710 Boundary Isyer attuctures and protesses PLANE GITS PROTEURICUM AR AN ATHOUPHERIC BOUNDARY

J. Ottornen (Tel Aviv University, Reset Aviv,

iscael)
A plane with protresions is analysed as a model for reacts sansing of the Earth's surface and for observations of solat irradiance at the surfate. The model is attend at representing the surface of otid regions where plants fore isolated of umps with large interstitutes of here soil. Applicability to other terrain types, such as attibute fields, tundes sed sevented appears possible. The protrusions (plants) are regarded as this vectical tylindors and the hey parameter, s, is the sun of belefit-fines-diameter products over a vertical tylindors and the hey parameter, s, is the sun of beight-times-diameter products ever a noit area. Remote seeming from a sun-synchronous matalitic (Landset) indicates the plausibility of the model, framents he in least-membequeres tit the model closely reproduces, as a function of the solar south angle, the reflectivities to tamith measured by Landsa's over an srid atempte, The explicit expressions for the hemisphoric reffectivities indicate a prenounced change in the sufface albade, as a function of the resith angle, of rerrain described by such souds. The solst heating of the protrusions constitutes as important component of the surs model. The solst heating of the protrusions constitutes an important responsing of the surgeous titutes and the solst action the sangle close to the torison. Show, the heating of ptorrusions can be a very significant part of the duly total surface heating (seen for a modernisty low s) when the poon would sow (i.e., at higher latitudes, aspecially in wiets). The interactions with the atmosphere facthange of sensible heating supportions/condensation processes) ors genetally quite different for the protrusions and the plane of the soil. In inferentions are aspectially different in the arid steppe, interact as the affective thermal institle of the protrusions incorrive dry busbes or tutsocfs) in host transfat to the processor is very low. This low thermal institle, and charifore marily intransfat to the Pizosphara Is very low, This low thermal inertia, and thetefore meanly inmediate transfer to the attouches of the soin irredients obsorbed by the pretrusions, is the dicated by radiation temporature measurements of the protreofone and of the soil condeted recently in a forced-off srow in the time!

2715 Chemical composition and chemical intersc-Tione
PEFECT OF MIFRAPYPIN ON EMISSION OF NITHOUS
OXIDE FROM SOIL FERLILIZED WITH ANHLOROUS

ARTONIA

J. B. brombot | Department of Agronomy, lows
Stats University, Ames, lows, 500111 G. A.

Oreitenbech, and A. M. bisckmor
flaid ntudies using a chambet technique to
agtours excissions of nitrous exids | Hypl nhouse
that the HyD eminsions | Induced by intrilitation
of noit with embydrous sements | 1100 cg M harly
user mathedly teduced by addition of nitrapytin
|2-chloro-6-(trichlotomethyli-pyridins) to this
estilland. The emission of Noi induced by chioro-6-(trishiotonethyli-pyridine) to this chilizer. The colasion of N10 induced by plication of anhydrous associatio the talt application of 22 by addition of nitrappin af the rate of 0.56 kg km⁻¹. The tottamponding reduction when n(trappin uma addind to ambydrous account applied to the applies was 07th observations indicate that nitrapy the value for reduction of the Fig.

Geophys, Res, Latt., Paper 1L0321

3715 Chemical somposition and chemical interac-

3715 Chemical Sosposition and chemical initials.

ENTHATING THE GOOME BUDGET IN THE BUDGDARY LAYER
BY USE OF AIRCRAFT HEASUMENENTS DY OZONE EDDY

FUIR AND NEAN CONCENTRATION
D. B. Lenechow (National Concert for Almospherit
Besserch, Boulder, CO 803DY) B. Fartson, Jr. and
B. S. Stankov

of feat response chemiumbosecent ownes common
ves counted in an BCAR Queen Air sirecait
issirumented for air motion, temperature and
hundricy wassurementer. The vertical file of
couns was then obtained by the adde correlation
techniques for enverte fitshes to the daytime
emospheric boundaty layer over seasore Colorado.
Bacausa of the range and mobility of the airoveff, this fachalques can be urtilized for a vida
oveff, this fachalques can be urtilized for a vida
oveff, this fachalques can be urtilized for a vida emospheric boundary layer over manera Control Bacausa of the range and mobility of the airorefr, this fachaique on he utilized for a vidal
variaty of situations. For example, e flight the
over en interestate bighway shows large negative
fluctoacions is Dr dua to vehicular esission of
NO which are veli-correlated with positive tempersture and varcical velocity fluctacions. On
one flight, the significant terms in the mean
onese communication budget land also, for compesison, the anamable hest and humbitly budgets)
vere avaluated from the airplane essurgments.
For this flight, which occurred under alear akiss
over range and oney land shout 100 hm northeast
of Denver, the time rate of change of osons
density in the lower helf of the boundary layer
ves shout 2.4 og m⁻¹e⁻¹. This was saverat class
larger than the contributions by horizonted
larger than the contributions by horizonted
flan of orone. Thus, most of the observed inresses in onese coacesfrethem must have been the
result of internal phacechanical production of
onesen. This sey he the first vell-documented
onesen. This sey he the first vell-documented
in shown to he belaced by photodumissi production of 0s. The deposition velocity of osons
for this case was about 0.47 cm s⁻¹
d. Osophya. Res., Orean, Paper 200441

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M'IS Chemical composition and themical interactions
SACKEPOUED NO, MIXING RATIOS IN ALE MARRES OVER
THE MORTH ATLANIC OCEAN
G. Mains and P. Unreach that-Pianck-freetitut
func Chemic, Mains, federal Republic of Certany)
A chemiuminentence analyser was used to ceasure No, mixing ratios at the wort comes of iraliand during the period June 11-27, 1079. NO was
determined ditectly, No. - NO + NO, alter convection of NO, by icon sulfate. In a third maneurement mode selog a molydenex convector higher
signals vers observed than with term sulfate,
ladiceting that ditrogen temporands ather than
NO + NO, are registered. They are designated
"arceas NO,". The average NO, mixing ratios
during the transign was 101 2 BY potw. In pure
series air masses fateralised by manes at trajectory seizulation, the NO, sleing tactor were
lower and schowd in Madifices a fatural variatlower and achowd in Madifices a fatural variatlower and achowd in Madifices a fatural variation with night line values of 37 f d pptw and a 24 b everage of 17 f A7 pptw. For such ton-ditions the MO mining ratio generally was less than 10 pptw. The surges to time settler air Amenan is also higher during the day compared with alght time values of about 70 pptv. Tut-that studies are required to identify the rom-pounds involved. | Earlyround Mg., earling attl. J. Gomphye. San., Organ, Papes 100495

3313 Chemical composition and chemical inter-

3113 Georgical composition and chemical Interactions
6108:AL ANALYSIS OF LOCAL VARIABILITIES IN 19305800:BL Golines and J. Peter Velp untioned
Applications, Inc., 1811 Sante Stia Food, Suite
104, Pleasanton, Ca. 435-bot.
A discrease and a second-relative to the colocontrol of the selected acrospheric values oldcontrol of the selected acrospheric values of
correct blooms, 1869, Notone 171, 1889.] conterming alformative interpretations of these
measurements, the provent analysis indicates that
current photochorical theory is consistent with
the saperfrontial observations of dismal vertations in total buy, butthers in, dismal vertations in total buy, and the selection of the postchemical mechanisms and of physical perturbations
when requisite levels of spatial and respects
tolum density, photochorical readerly, stratesphere, dismal variability, trace species in the
atmosphere. almospherel. J. Geophym. Bem., Green, Paper It 0|40

Fig. Geophys. Bes., Green, Paper L.0140

Fig. General cirtulation

NORTHEY AND SASSMAN VARIABILITY IN THE OCIAN-PEPATROPHEES SEFERS OF HIS ROPHI PACIFIC AND THE

KOSTH ATLACTIC

J. F. Maish liberatory for Atmospheric Research,

Interestly of liftness, Urbana, illinoise cidely

and J. E. Sajer

Foor regional Indices of weakley variability

and thirty years of mentily sea surface respecta
ture 15571 and sea level present price than are

used to evaluate the large-major interest from

within the occum-ine-atmosphere swares of the

Sorth Pacific and the Sorth Minnite. A direct

association between positive inequalized 157

annualizes and Light heavy for the the Pacific

Sea is indicated. The Stiff dee coupling to the

northern Alanam waters is also utariated the

significant. The Stiff annualizes in hoth the

Sorth Pacific indite North Adamtic appear of

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significant, which waters is 157 direction in

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RORMAL MODE BUTTALIZATION
RORMAL MODE BUTTALIZATION
Regarch, P.O. dos 10:00, Daulet, Colorados
The batoriloit printitive equation models used for short and radius range usether loraneating staft undestable high frequenty gavety waves. The gravity waves are excited by iditiat inhalances between the obserted wind and tax lields and by inconsistencies between each and escomplers. Over the years, tamy idittalization techniques have been devised to balance the initial state, but Sithout notable success. The treest introduction of normal mode initialization techniques has, to a large degree, solved the publica. The present review will discuss the development of the tachsique from itret pricipies, introdure the slow zaoifold tencage and discuss tuccessful applications and recasing problems.
Rev. Scophys. Spice Phys., Paper 190315

1735 Interetion of atmosphere wish minestrongnutle wares
05250x710MS of tigar Ale TurbulEntf Aro Wisos
With The Millighor Sitt RADAR
5. J. Mathins Northmett Bedio Observatory Corp.,
Hoystach Observatory, Vettfetd, MA 01886) and
A. M. Veed
The Milliatons Bill Abo Miz rader at Ventford,
Matesachusett het been upgraded for studiat of
turbulence and windt in the troposphere and lower
stratosphere. Uteful date have been obtained up
to 20 km altituds. The rader hes been obtained up
to 20 km altituds. The rader hes been obtained up
to 20 km altituds. The rader hes been obtained up
to 20 km altituds. The rader hes been obtained up
to 10 bac and a pulss repellation of 500
Hz. The 150 foot diamater tigereble entanns hat
been sind differently in three types of experimente, (e) Antenna selenth scant with fiend elevetion, (b) elevetion scan with fiend elevetion, (b) elevetion scan with fiend elevetion, (c) Antenna apprisentt ten obtain both the
herizontel and vertical wind components. Antenne
eleveticate sean heur bean sted to leventicate the

nergones and wortes and the constant for a season have been sted to leventing the horizontal structure of turbulents. The fixed antenne seperioses provide sendings resolvation and are useful for studying the occurrence of wave. Wave: In both the velocity and to, the refrective indee turbulence structure constant, have seen frequently observed at heights east the tropopause and below. The wavet hare periodt 10 20 minstes and have been leterpreted as Emjeren

Nam found is occar |1-2-km) below the Jevel of a valocity shear. Navet generally paralat for tearral cycles.

Using anishns elevation tean method the level of turbulence les measared by the Cg velue) hat been pettured at points asperated by 10-20 kms. Morf-zoneal patches of turbulence have been found that appear to move with the wind.

J. Geophys. Kens. Otens, Papot LCD191

2710 Partiales and Acrosole
Di The ROLE of PHONO-INDUCED SOLUTION REACTIONS ID
DETERMINING ATMOSPHERIC AEROSOL CONCENTRATIONS
P. Hiddbeton, firthonal Center for Atmospheric
Basearch, P.O. Bon 2000, Boalder, CO 80307)
The role of photo-induced solution reactions in
delarmining atmospheric aerosol concentrations in
delarmining atmospheric aerosol concentrations in
discussed ead investigated with incorrections in
considered is the conversion of discoved O; into
H₂O; which can then react with dissolved So; and
MO; to form sulfals and nilests. The res of this
reaction is compared to the rate of H₂O; formalisa
In molation from diffusion and absorption of
H₂Os get in the servoi serface. The influences
of H₂Oc concentration and aerosol size on the
relative rates are favestigated. It is found that
the photo-induced solution reaction rate is seach
lower than the 9th diffusion rate has rate is seach
lower than the 9th diffusion rate has not becomes incre
competitive ae particle aizs increment.
Jacrosola, solution photochemitics, H₂O₅, sulfate,
elirate).
J. Geophyn. Res., Otean, Yeper 100333

Mineralogy, Petrology, and Crystal Chemistry

ARTO Experimental minoralogy and potentialy PMASE SELATIONSPRES OF SHIPE CRANITY WITH MY TO 1. KM. HUSCOVIES GRANITE FORM HANNEY PEAR, SOUTH

MIFOTA

W. L. Hunng and P. t. Wyllis interactions of complication Sciences. University of Chicago, Chicago, 11. 604ft1

Buscovite granter (12.8f nuscovite, 4.8f nurcivite countril was reacted, with varying purcentages of 11.0. In cold-seal vassels at 2 bb and in piaton-cylindar apparatus between 10 and 3) 30. The diagrams liturating calling crystallication relationships are: P-f sections

and in pision-cylindar apparatus between 10 and 33 bb. The diagraca illustrating colling! crystallitation relatiouships are: P-f sections with both excast M-00 and with a mounte of a lucatoral light on of quartraferesite found in arounce of a lucatoral light of compositions of quartraferesite found in arounce of a lucatoral light of compositions required by electron of exceptions of from anythm with 35 M/O at 12 th continue that lightly are specific to apprehend any excited of pressure on the Residual Swatch. Reculte one applied successfully by phase relationships indefined accessfully by phase relationships indefined accessfully by phase relationships indefined accessfully by phase relationships indefined and protail of the diversions surface in the region P-10 in 10 i

4260 Paragamesti, petrography, and petrogenetis file RCOSKII GRAVILE--CVIDENCE (OR MERMO-GRAVILE-IVIDENCE (OR MERMO-GRAVILE) (DAVILE--CVIDENCE (OR MERMO-GRAVILE) (DAVILE) (DA

A26D Perseguesis, parformarby, and partoganetia THE LATE-ARCHARAN GORQUY GRANITE COMPLEX OF

A250 Perseguesis, perforaçby, and pattoginetia IRC LATE-ARCHALAN QUAQUT GARNITE COMPLEX OF SUUTHERN WEST CARRILLAN QUAQUT GARNITE COMPLEX OF SUUTHERN WEST CARRILLAND MICHAEL STATEMENT OF CARLEY STATEMENT OF CARLEY STATEMENT OF CARLEY STATEMENT OF CARLEY Pland V.S. McGragor and C.T. Parktus

Granicas and gasmite pegmatitus comprising the ca. 2550 Ma Gorqut granite complex occur in n 35M-NNI-creating linear bet 1150 but integ extension through the Buhnerjorden - Ameralik - Godchhafford regton of scushero West Greeniaci. The main body of the complem crops out over a dissance of 50 km faces Ameralik co Xaplaigdic Sangerduss and ranches a maximum outcop width of 10 km between Storf and Gorqut. Around Gorqut. Around Gorqut in the complem crops of granitael arrly isuscotracic greelres; various grap bintile granises; ond size aprogramita - grantes arrly succotracic greelres; various graphentia garditus with a complem has complem has a tripsette extiture comprising a Lower Zone dominently of polyphase granits, an interesdiate Zone where compley rock necessian at the polyphase granita with a complem sheeted by granite. Si apocleons of granita have heen onelyed for adjor, minor and ame State elements. Seathered variety of constry rock sheeted by granites. Si apocleons of granita have heen onelyed for adjor, minor and ame State elements. General varietion wishin the complem is tousiatess with elits; fractioned crystatilestion or pastic maint have heen involved either affectionating phases or as readual phess after exicled to eccount for the trace element thaniatry. No possible models for the gaseration of the complem est readed for the gaseration of the complem est element despine deprise feets rocks to the investigate depins of amphibotis feets rocks in the investigate, georgical dy, J. Danphyn. Res., Ead, Fapar 1800at

4270 Properties of minerals MAJDRITE: VIERATIONAL AND COMPRESSIONAL PROPER-TIES OF A HIGH PRESSURE PRASE Raymond Jeaning (Department of Geological Sciences, Hereard University, Cambridge, MA 02116)

Majorits, the garnot-structured high-pressure Majorits, the garnot-structured high-pressure phase of pyrosone, has been christerised by infrered [18] spectroscopy, and X-ray diffrattion between 0 and 0 feet [60] heer). In this attracture, three out of four [Mag.fe] are leading to the significant line and one out of feet it to ais fold coordination and one out of feet it to ais fold coordination. Into IR spectrum indicates the edittrace of large tetrahedral ditiortions, probably associated with the small tetlem radii (tignificant associated with the small tetlem radii) (1970) and 1871 [Mag.7gfeg.2][310] the little parameter and dealth are as a 1864 Alchibus associated with the contraction). dentity are | e = 1)54.4)c0.|) pm and o = 3.131 (t0.001)Mg/m³. Mydrostalic comptation mattura-menta yield a sero-prottyre belk modalus and its pressara derivative of F_Q = 221(215) GPs and Kn - 4.4(\$4.0). The composition-dependent calone and bulk modoles in the system pyropa-tlandins-majorite are well constrained by the present deim: for majorite, these ere substantially scaller and larger, tempetively, thus predicted by systematics for paroett. Electricity systematics for paroetts for the second control of the systematics of the

attle prosides a satisfactory correlation. In transforming to Migher pressure phass beyond adjusted (with substantially higher densitiat), peragene does not dechibit algoiffcont increases to bulk gound velecity. Transformation to majo-rite probably occurt within the upper mantia and further phase intentitions in pyresses may be difficall to observe selecologically. J. Camphya. Rus., Red., Tayer 180492 Campaya. Res. Red, Tayer 180492